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A MICROCOMPUTER-BASED SIGNAL DATA CONVERTER FOR RUNWAY VISUAL R--ETC(U)
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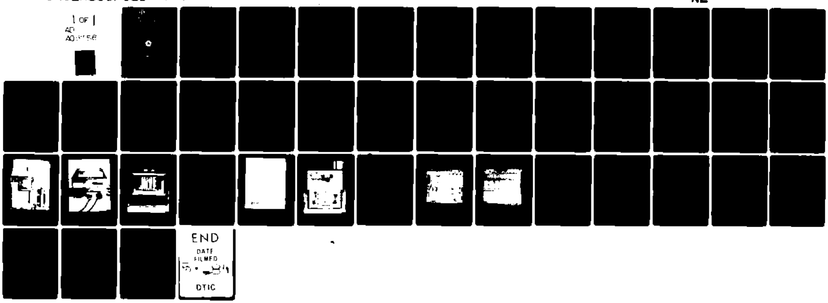

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A MICROCOMPUTER-BASED SIGNAL DATA CONVERTER FOR RUNWAY VISUAL RANGE MEASUREMENTS.

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FINAL REPORT

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16. Abstract

A laboratory model microcomputer-based Runway Visual Range (RVR) System was designed and built at the Federal Aviation Administration (FAA) Technical Center. The system includes a Microcomputer Signal Data Converter (SDC), a Remote Display, a local maintenance terminal, a cassette storage unit, a Transmissivity Display, and a Transmi someter Simulator. The Microcomputer SDC computes RVR values for up to 12 transmissometers; previous SDC designs can calculate RVR values for only 1 transmissometer. Furthermore, the microcomputer-based RVR System provides alarm checking, data storage, and RS-232 compatible data outputs that are not available in other RVR systems. Based on the improved capabilities and the microcomputer's low cost, it is concluded that Microcomputer SDC's would be cost effective at airports using more than three transmissometers.

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METRIC CONVERSION FACTORS

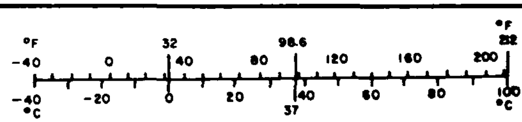
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.036	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

PURPOSE.

The purpose of this task was to design and develop a microcomputer-based Runway Visual Range (RVR) Signal Data Converter (SDC) and demonstrate its performance in a simulated environment. The results of this task will support decisions for future RVR implementations.

BACKGROUND.

As part of the Interservice Agreement (9550-AAF-501-78-002) for the Remote Maintenance Monitoring System (RMMS) Program, the Federal Aviation Administration (FAA) Technical Center was tasked to design and develop an RMMS test bed. The test bed would consist of several remote site microcomputers monitoring the Instrument Landing System, Approach Lighting Systems, and the RVR System sites at the Technical Center/Atlantic City Airport. A central minicomputer would communicate with and collect data from the remote sites via dedicated land lines. The central computer would also drive maintenance displays.

The commissioned RVR System at the Atlantic City Airport consists, in part, of three Tasker Systems RVR-400 SDC's. As part of the test bed, a single microcomputer was designed and built that simultaneously monitors all three SDC's. In order to properly monitor the SDC's, the microcomputer had to perform all the tasks of all SDC's, except drive remote displays. Under the Consolidated Cab Display (CCD) Program, the central computer would drive new type displays, eliminating the need to drive existing RVR displays.

The capability of the microcomputer-based RVR monitor demonstrated that existing SDC's could be replaced by microcomputers. If all the SDC's at an airport could be replaced by a single microcomputer, significant cost benefits would be achieved. Furthermore, microcomputers could provide an improvement in overall system performance (particularly in alarm checking).

RUNWAY VISUAL RANGE BACKGROUND.

An RVR System is used to measure visibility along a runway. An RVR value, measured in feet or meters, indicates the horizontal distance the pilot will be able to see down the runway. These values are often computed at three locations along the runway (touchdown, midpoint, and rollout) to account for differences in atmospheric conditions.

A typical existing RVR system for a runway is shown in figure 1. Transmissometers are located at the touchdown, midpoint, and rollout areas. A transmissometer is a device that measures the transmissivity or the relative clearness of the atmosphere. It consists of a light source (projector) and a light receiver separated by 250 feet. This distance is called the baseline. The transmissometer receiver produces a pulse train output proportional to the amount of light received from the projector.

The output from each transmissometer receiver is transmitted via land lines to an SDC. Each SDC counts the transmissometer pulses for a fixed interval. It also acquires the runway edge light level intensity setting and the ambient light sensor setting. These settings determine which RVR value table in the SDC is selected. The SDC performs a table look-up procedure that produces an RVR value corresponding to the transmissometer pulse count and the two light settings. An SDC is capable of calculating an RVR value for only one transmissometer.

Each SDC provides an output signal that drives remote displays used by air traffic control specialists (ATCS). Each remote display may acquire and display up to three RVR values. An ATCS may set minimum RVR value limits on the display. If the RVR value drops below the minimum an alarm is activated.

The system shown in figure 1 provides accurate RVR values between 600 and 6,000 feet. For greater accuracy at RVR values less than 600 feet, the transmissometer receiver should be moved closer to the projector. The Tasker Systems RVR-500 employs the dual baseline concept to provide accurate RVR values from 100 to 6,000 feet. The dual baseline system uses two transmissometer receivers: one at the typical 250-foot baseline, and the other located 40 feet from the projector. When RVR values drop to 600 feet, the SDC automatically switches from the long baseline receiver to the short baseline receiver. When the RVR value increases to 1,000 feet, the SDC switches from the short baseline receiver to the long baseline receiver. During the switching operation a 1-minute delay in computing RVR values occurs.

The FAA Technical Center's task was to design and demonstrate a microcomputer-based system in the laboratory that could replace all the SDC's required at an airport. The RVR system was planned to be integrated into a CCD system. The CCD central computer would receive RVR data from the microcomputer and use that data to drive its own displays. To demonstrate the versatility of the microcomputer system, a remote display was also designed and built. In this way, the microcomputer system could be used either in a CCD system or as a stand-alone unit.

To adequately test the RVR microcomputer, a transmissometer simulator was designed and built. This device simulates 12 transmissometer receiver outputs. A description of all the devices designed at the Technical Center is provided in the Detailed System Description section of this report.

SYSTEM OVERVIEW

A block diagram of the microcomputer-based RVR System is shown in figure 2. The system is designed to provide RVR information for up to 12 transmissometers. The main components of the system are the Microcomputer SDC, the Transmissometer Simulator, and the remote display. In addition, the Microcomputer SDC interfaces to a local cathode ray tube (CRT) maintenance terminal, a cassette tape storage unit, and a transmissometer bar graph display. Figure 3 shows the SDC, the Transmissometer Simulator, local terminal and cassette storage unit (TermiNet 30).

The Transmissometer Simulator (figure 4) provides 12 independently programmable pulse generator output channels. Each channel may be programmed for the range from 0 to approximately 4,200 pulses per minute. The simulator will also respond to background count commands from the Microcomputer SDC by lowering the appropriate transmissometer channel output to about 12 pulses per minute. (Background counts are the number of transmissometer output pulses, for a fixed interval, when the transmissometer projector is off. An actual transmissometer count is the transmissometer count minus the background count.)

In an actual RVR System, transmissometer output pulses may vary over a wide amplitude. In addition, background count command signals from the SDC are transmitted over the same pair of wires that bring the transmissometer pulses to the SDC. In this microcomputer-based system, however, all signals to and from the simulator are at transistor-transistor logic (TTL) levels, and background count commands are sent over separate wires. This approach was

chosen because the Microcomputer RVR System is a laboratory demonstration model and the signal conditioning that would have been required is neither unique nor relevant to the Center's task.

In addition to the transmissometer output pulses, the simulator has a group of switches that simulate the runway edge light level sensor outputs (there are simulated sensors for four runways) and two switches to simulate the ambient light sensor output.

The Microcomputer SDC (figures 5 and 6) acquires all 12 transmissometer pulse outputs and light sensor outputs from the simulator. The transmissometer pulses are sent to a set of 12 counters. Every 15 seconds the microcomputer central processing unit (CPU) acquires the counter values and resets the counters. A running 60-second total count is kept for each transmissometer. For each transmissometer, the microcomputer selects a particular table based on the acquired light sensor information. Then from that table, an RVR value is selected that corresponds to the last 60-second count for that transmissometer. Table 1 is a typical RVR table. The tables used in the Microcomputer SDC are the same as those used in the Tasker RVR-500 SDC.

The RVR value and associated data (i.e., transmissometer counts, background counts, and light sensor values) are formatted for output to the remote display, local maintenance terminal, local transmissivity display, and cassette storage. In addition, transmissometer counts are compared to maximum and minimum limits, background counts are compared to a maximum limit, and the RVR values are compared to minimum limits. If any of these values are out of tolerance, alarm flags are set and an audible alarm is sounded on the local terminal.

The RVR data is updated every 15 seconds. This data is sent to the remote display, transmissometer display, and the storage tape. The local terminal receives data only upon request.

Data sent to the remote display includes all 12 RVR values, light sensor data, transmissometer and background alarm data, relative change in the RVR value since the last update, and whether or not a background count is in progress. Data sent to the cassette storage unit include time, all RVR values, light sensor data, alarm data, and whether or not a background count is in progress. The transmissivity display consists of three light emitting diode (LED) bar graph displays. The bar graphs display transmissivity percentages for three transmissometers.

When alarms occur, the local maintenance terminal receives audible alarm commands from the microcomputer. All other data to the local terminal are upon request. Microcomputer date and time may be changed, background tests initiated, and alarm status and RVR data may be obtained via the local terminal keyboard. The data displayed for each transmissometer includes the RVR value, latest transmissometer 60-second total count, latest background count, light sensor status, and the relative RVR value change since the previous data were taken. Typical display data at the local terminal are presented in figure 7.

The remote display (figures 8 and 9) receives and stores the RVR data for all 12 transmissometer channels, and displays RVR values for any 3 of the 12 channels. Data displayed for each channel include RVR value, light sensor status, alarm status, relative RVR change, and whether or not a background count is in progress. RVR channels are selected via a hexadecimal keyboard on the remote display. Minimum RVR value

TABLE 1. TYPICAL RVR VALUE TABLE

Ambient Light Condition - Day
Runway Edge Light Intensity Level - 4

Transmissometer Pulse Count	RVR Value (feet)
Short Baseline	
26	0
381	100
1151	200
1777	300
2227	400
2552	500
2792	600
2975	700
3177	800
3363	1,000
Long Baseline	
241	0
423	600
629	700
948	800
1352	1,000
1705	1,200
2005	1,400
2258	1,600
2470	1,800
2650	2,000
2802	2,200
2932	2,400
3018	2,600
3077	2,800
3146	3,000
3250	3,500
3356	4,000
3435	4,500
3497	5,000
3547	5,500
3578	6,000
4094	6,100

limits for each channel are set via thumbwheel switches and an alarm is displayed if the RVR value falls below that limit.

DETAILED SYSTEM DESCRIPTION

MICROCOMPUTER SIGNAL DATA CONVERTER.

The microcomputer SDC is based upon the Z-80 microprocessor. The entire SDC consists of five boards (each is 7.7 by 7.5 inches) housed in a single card cage. Three are printed circuit boards available commercially from Zilog, while the other two are wire-wrap boards designed at the FAA Technical Center.

The Zilog boards are the Microcomputer Board (MCB), Serial Interface Board (SIB), and the PROM Memory Board (PMB). The MCB contains the Z-80 microprocessor, eraseable programmable read only memory (EPROM), random access memory (RAM), an RS-232 serial interface to the local terminal, a clock timer circuit (CTC), a parallel input/output (PIO) chip, and the necessary logic and buffering to allow the CPU to transfer data to and from memory and input/output (I/O) devices. The SIB provides four RS-232 serial interfaces: one interface drives the remote display, a second drives the cassette recorder, and the remaining two are spares. The PMB is an EPROM memory expansion board. Typical Zilog printed circuit boards are shown in figures 10 and 11.

One wire-wrap board consists of the transmissometer counter circuitry and the light sensor interface circuitry. The other wire-wrap board contains driver circuitry for the transmissivity display.

A simplified block diagram of the entire microcomputer SDC is shown in figure 12. The Z-80 microprocessor chip is the system CPU which controls all operations of the SDC. The software instructions that the CPU uses to control the system reside in EPROM. All collected data are stored in RAM. Instruction fetches by the CPU and data transfers between the CPU and memory or I/O devices are accomplished using the address bus, data bus, and control lines.

The 12 transmissometer counter circuits consist of four Intel 8253 programmable interval timers (PIT's). Each PIT has three independent 16 bit counters. The transmissometer simulator outputs drive these counters. Background counts are initiated on a particular channel by setting the appropriate bit on a latch in the background interface circuit. The Transmissometer Simulator senses the high state of the latched bit and responds with a low pulse rate for that channel. When the bit is reset, the simulator returns to its previous pulse rate.

There are four ambient light sensor states: night, twilight, day, and bright day. The state is defined by the status of two bits on the ambient light interface (i.e., bright day = 00, day = 01, twilight = 10, and night = 11). The bit status is determined by switch settings in the transmissometer simulator.

Similarly, there are four runway edge light intensity level settings (0-2, 3, 4, and 5) used by the SDC. The runway light interface acquires intensity level settings for four individual runways from switch settings in the Transmissometer Simulator. For each simulated runway, three status bits are used to define the runway edge light level. Intensity levels 3, 4, and 5 each have a status bit associated with it. The one bit of the three that is set indicates the current runway light level. If none of the bits are set, the light level is 0-2. Since there are four ambient light states and four runway edge light levels used, a total of 16 different light combinations are possible. For this reason, there must be 16 separate RVR tables in the computer.

Data are transferred between the microcomputer and the remote display, local maintenance terminal, and cassette recorder using RS-232 serial interfaces. In each case, an Intel 8251 Universal Synchronous Asynchronous Receiver Transmitter (USART) chip is used. A USART receives parallel data from the computer and outputs the data to an external device serially. Data are received from external devices, serially, and converted to parallel data, which can be transferred to the computer via the data bus. In order to operate at RS-232 levels (±12 volt signal swings), line drivers and receivers are required. The drivers and receivers are at TTL levels at the USART interface, but are at ±12 volt levels on the side directed to the external devices.

Data are transmitted to the remote display and the cassette recorder at 1200 baud, and are transmitted to and received from the local terminal at 4800 baud. All data are transmitted in the USART's asynchronous mode. For all three outputs, modems may be installed allowing data transfers over telephone lines. In this way, data may be transferred an unlimited distance.

The transmissivity display interface drives three General Instrument MV57164 LED 10-segment bar graph displays. Each segment of a bar graph represents 10 percent of the total transmissivity. For example, if the first seven segments are lit, the transmissivity is between 70 and 80 percent.

In the laboratory model SDC two types of transmissivity display interfaces are used: digital and analog, to demonstrate different approaches. In the digital approach, the microcomputer software determines the sequence of bar graph segments that should be lit. The CPU then outputs this sequence to latches at the display interfaces. The latches are interfaced directly to the bar graph and light the appropriate segments.

In the analog approach, the transmissometer count is output by the microcomputer to a digital-to-analog (D/A) converter. The D/A output provides an input to a 10-segment dot-bar generator. Based on the input analog voltage, the dot-bar generator will light the appropriate bar graph segments.

The digital approach uses less expensive and fewer components than the analog approach. However, the analog approach provides an output that can be used to drive strip chart recorders. The present Tasker RVR Systems record transmissivity on strip chart recorders. In the Microcomputer SDC, transmissivity can also be obtained from the digital data stored on the cassette recorder.

A system clock (2.4576 megahertz (MHz)) is required by the CPU, CTC, and USART's. The CTC, which consists of four independently programmable counters, generates baud rate clocks for the USART's and a 1 hertz (Hz) clock for the CPU. At 1-second intervals the CTC triggers the interrupt line on the CPU. The CPU responds by transferring its software execution to an interrupt routine. In this routine, a real-time clock is updated. Once every 15 interrupts the transmissometer data are collected from the counters.

TRANSMISSOMETER SIMULATOR.

The transmissometer simulator unit consists of two printed circuit boards housed in a single card cage. One board is a Zilog MCB; the other is a wire-wrap board (WWB) containing circuitry designed at the Technical Center. The MCB is identical to the one described in the Microcomputer SDC hardware description; however, a different program is stored in EPROM. All user controls are mounted on the front panel of the card cage (see figure 4). The controls consist of one hexadecimal thumbwheel switch, two decimal thumbwheel switches, one normally open pushbutton, two single-pole single-throw switches, and a two-character hexadecimal display.

The MCB contains the Z-80 microprocessor, EPROM, RAM, CTC, PIO, and the associated logic and buffering circuits for proper operation of the MCB and all I/O devices. The program is stored in EPROM; all temporary data are stored in RAM. Other logic on the MCB controls all I/O signals to and from the WWB.

The WWB contains the logic and circuitry to generate simulated transmissometer pulses and to receive background count requests from the microcomputer SDC. It also contains interface circuitry to acquire the front panel switch settings and drive the displays. Dual in-line packaged (DIP) switches are also provided to set runway light levels and ambient light levels.

A simplified block diagram of the transmissometer simulator is shown in figure 13. The Z-80 CPU controls all operations of the simulator. Instructions for the CPU are stored in EPROM. Data collected from the front panel switches are stored in RAM.

CTC No. 0 generates timing interrupts to the CPU and clock inputs to the remaining four CTC's. Each CTC (Nos. 1 through 4) provides three independent programmable counter channels. The narrow pulse outputs of these 12 counter channels are converted to square waves and sent to the Microcomputer SDC as simulated transmissometer pulses. The output frequency of each channel is determined from the switch settings on the front panel. The switch settings are acquired by the CPU from the switch interfaces.

Front panel switches are also used to select the channel to be displayed on the front panel display. The selected transmissometer channel's output is gated to a counter in the display driver circuitry. The counter output drives the display.

The background interface acquires the status of the Microcomputer SDC background count request. If a received bit is set, a background count for a particular channel has been requested, and the simulator provides a slow pulse rate for that channel.

The set of DIP switches used to simulate runway edge light intensity levels and the ambient light levels are independent of the simulator computer. The switch outputs are sent directly to the light interfaces on the Microcomputer SDC.

REMOTE DISPLAY.

The RVR Remote Display consists of two circuit boards (a Zilog MCB and a wire-wrap board) in a single card cage and a display panel, housed in a standard 19-inch relay rack cabinet (see figures 8 and 9). The front panel uses both hexadecimal displays (Hewlett-Packard 7340) and ASCII displays (Litronix DL-1418). All user controls are mounted on the front panel. These controls are an on/off switch, a program reset button, minimum RVR limit thumbwheel switches, and a hexadecimal keypad for the RVR channel display selection. Data for the remote display are received over a single RS-232 channel from the Microcomputer SDC.

Figure 14 is a block diagram of the Remote Display. System operation is under control of the Z-80 CPU; the operating program is stored in EPROM. All temporary data are stored in RAM.

The keypad interface consists of a Harris HA-0165 keypad encoder and a Zilog PIO chip. When a key is depressed, the encoder provides both a four bit binary output representing the key depressed (0-9, A-F) and a strobe signal. The PIO acquires the encoder data during the strobe signal. Every time the PIO receives data, it interrupts the CPU, allowing the character

depressed to be transferred to the CPU and then to RAM.

An Intel 8251 USART receives serial data from the SDC. The USART output is then acquired by the CPU and transferred to RAM.

The selected RVR values are transferred from the CPU to the three hexadecimal displays via the RVR value display driver. System status information for the three selected channels are transferred from the CPU to the ASCII displays via the status display driver. Status information consists of ambient light conditions, the runway edge light levels, alarm status, and the change in the RVR value since the last data calculation.

The thumbwheel switch interface receives the front panel thumbwheel switch values. The CPU then acquires these data from the interface. The switches allow ATC personnel to set minimum RVR value limits. If an RVR value falls below the limit, the appropriate status display will indicate an alarm.

LOCAL MAINTENANCE TERMINAL.

A Hazeltine 1520 CRT terminal, operating at 4800 baud, was used as the local terminal (see figures 3 and 7). Any RS-232 compatible terminal can be used.

CASSETTE RECORDER.

A General Electric Terminet with a magnetic tape terminal was used (see figure 3). This particular system has two tape drives and can record at rates up to 1200 baud. Any RS-232 compatible cassette recorder can be used.

THEORY OF OPERATION

MICROCOMPUTER SIGNAL DATA CONVERTER.

The microcomputer signal data converter is a hardware system under software control. The software consists of an initialization routine, a main routine, and an interrupt processing routine. The program is written in Z-80 assembly language and PLZ, Zilog's higher level language. Approximately 12000 bytes of EPROM and 2000 bytes of RAM are used.

When the CPU receives a reset pulse the CPU executes the initialization routine starting at address zero. The initialization routine sends initialization commands to the programmable I/O devices (the 8251 USART's, the Z-80 CTC, and the 8253 counters). Software flags and counters are then initialized. Transmissometer counts, background counts, RVR minimum limits, etc., have initial values set. Background test procedures for all channels begin. Interrupts are enabled. "TYPE H FOR HELP" is displayed on the local terminal. Program control is transferred to the main routine.

The main routine (the flowchart is shown in figure 15) begins by testing an RVR status byte "FLAG." FLAG is set by the interrupt processing routine if RVR data have been collected. If the main routine test shows FLAG is set, then data are formatted and transmitted to the remote display via the USART. Each time a character is output to the display, the local terminal service routine is called. This is done to insure that local keyboard entries won't be lost during the time data are being sent to the remote display.

After the complete message is sent to the remote display, similar data format and data output routines to the cassette recorder are executed.

The transmissivity display data are then formatted and sent to the display driver circuitry. At this point, FLAG is reset and the program calls the local terminal service routine. If FLAG had been zero at the start of the main routine, the program would have jumped directly to the local terminal service routine call statement. After execution of the local terminal routine, the program jumps back to the start of the main routine and repeats the procedures just described.

A simplified flowchart of the local terminal service routine is shown in figure 16. A status byte "FIRST" is checked. If FIRST is zero, then the routine is waiting for a new request for data from the terminal. If FIRST does not equal zero, then at least the first character of a data request from the terminal has already been received. Based on the value of FIRST, the program execution jumps to a subroutine.

In every case, the status of the receiver ready bit of the USART receiving data from the terminal is tested. If the bit is not set, program execution returns to the main routine; if the receiver bit is set, a character is read into the computer.

If FIRST had been zero, then the character just received is a one-character message requesting action by the microcomputer. The received requests are as follows:

- T - Time Update
- D - Date Update
- R - Output RVR Data
- L - Change Minimum RVR Limit
- B - Institute a Background Test
- A - Output Alarm Data
- C - Change the Runway Designation of a Transmissometer
- H - Output a Message Defining the Above Characters

After the request has been defined, FIRST is set equal to a new value and an appropriate subroutine is called. For example, if an R had been received, FIRST would be set equal to three and a subroutine called "ENTRWY" would be called. ENTRWY would output a message to the local terminal requesting the terminal user to designate which transmissometer RVR data were desired. Program control would be transferred to another routine (called "ED") which would await the terminal users reply message. Once again, the receiver ready status bit is tested. If no character is received, program control is returned to the main routine. However, the next call to the local terminal service routine will be routed to the ED routine.

Once the total message is received, routine "FRWY" is called, which locates the desired transmissometer data and outputs the data to the local terminal.

Message sizes to the local terminal vary. Communications is at 4800 baud. The largest message sent to the local terminal takes less than 2 seconds. The message to the remote display consists of 194 characters. At 1200 baud it takes approximately 1.6 seconds to complete a message. Similarly, the 164-character message to the cassette recorder takes approximately 1.4 seconds. Outputs to the transmissivity display occur in microseconds.

Main routine execution is interrupted once a second. As described in the system hardware description, a CTC chip provides a 1-second timer. At 1-second intervals, it drives the CPU interrupt line low. This action causes the program execution to be transferred from the main routine to the interrupt processing routine.

A diagram of the interrupt processing routine is shown in figure 17. A software counter called "TIMER" is decremented. If TIMER equals zero, it is time for the 15-second data update.

A subroutine to acquire data from the 8253 counters is called. TIMER is reset to 15, the FLAG status word used in the main routine is set, and "DATRDY," a byte similar to FLAG used in the main routine, is set. Finally, a routine to update the real time clock is called.

If TIMER doesn't equal zero, the program loops around the data acquisition routine, resets DATRDY to zero, and then calls the real time clock routine.

If TIMER equals five, a subroutine to check for background test requests is called. If a request for a background test for a transmissometer channel had been made in the previous 15 seconds, then the background test is initiated at this point. The 5-second mark was chosen to allow 5 seconds for the transmissometer projector to shut off completely. After completing the background routine, the program returns to the main routine.

If TIMER does not equal five, DATRDY is tested. If it equals zero, the program returns to the main routine. Otherwise, RVR data are computed from the lookup tables. A test to determine which channels are in background counts is conducted. If a channel is in a background count, a "B" is added to that channel's data buffer. Alarm limits are checked. All data are converted into ASCII code. A check of the background counts is made again. If a channel background count has been in effect for 60 seconds, the background test circuitry for that channel is reset. Finally, the program execution returns to the main routine.

TRANSMISSOMETER SIMULATOR.

The transmissometer simulator is a hardware unit under software control. All functions of the unit are controlled by the program. The unit's purpose is to provide 12 variable frequency square-wave outputs to drive the microcomputer SDC.

There are three routines in the program: the initialization routine, the front-panel switch driver routine, and the data conversion routine. All routines were written in Z-80 assembly language.

When the RESET button is pushed, all I/O devices are reset and the interrupts are disabled. Program execution automatically begins at location zero. At this point, the initialization routine begins. In this routine, the MCB CTC (CTC No. 0 in figure 13) is programmed to provide a 1-Hz pulse for interrupts, and 300-Hz pulses to drive the transmissometer CTC's (Nos. 1 through 4 in figure 13). Also, the data areas in RAM are zeroed out to prevent any incorrect program execution.

Program execution is then transferred to the front panel switch driver routine. This routine processes signals from the front panel switches. Thumbwheel data containing the appropriate channel number and desired output frequency are input and stored. This information is used to determine the appropriate command words and time constants needed to program the desired transmissometer CTC channel. Thumbwheel switch data are also used to drive the frequency display.

Once every second CTC No. 0 triggers the CPU interrupt line and program execution is transferred to the interrupt routine. The interrupt routine contains the software to process the background request bits from the SDC. The 12 bits are input from the SDC, 6 at a time, once every 3 seconds. Two checks are made on each bit. First, if the bit is set, a background count is to be initiated on that channel. Second, a software status byte for each transmissometer channel is checked. If this byte is set, a background count is already in progress. In this case, the channels status remains unchanged. If bit 7 is clear, the channel is in normal operation. In this case, the proper constants are loaded

into the appropriate transmissometer CTC channel and the background count is started. If the background is clear, then the CTC channel is either reset to its previous frequency, or it is left unchanged.

REMOTE DISPLAY.

The remote display is a hardware unit under software control. All functions of the unit are controlled by the program.

There are four main routines in the program. These routines are the initialization of I/O devices and storage locations, the main routine, the keypad interrupt routine, and the serial data interrupt routine. All software was written in either Z-80 assembly language or PLZ.

When the RESET button on the front panel is depressed, all interrupts are disabled in the Z-80 and I/O devices. Program execution begins at location zero. At this point the initialization routine begins. The PIO is programmed to be in input mode and the PIO interrupts are enabled. The PIO will generate an interrupt when a strobe signal from the keypad encoder occurs. The CTC is programmed to generate a 1200 baud rate clock for the USART. Also, the receiver ready line from the USART down counts channel 3 of the CTC. Since channel 3 is loaded with a count of 1, every down count will provide an interrupt to read in the received character. The USART is programmed for 8 bits per character and odd parity. At the end of the initialization routine, the RAM is zeroed out to prevent any incorrect first display. Program execution is then transferred to the main routine.

The main routine is shown in figure 18. The thumbwheel switches with the RVR minimum value limits are acquired. The three values are converted from BCD to binary and stored in RAM.

A data ready flag is tested. If the flag is set, it means the serial data interrupt routine has received a complete message from the microcomputer SDC. If the flag is zero, the test is repeated.

After the data ready flag is set, a test is made to determine if a new RVR channel has been selected for display. New channel selections are initiated by depressing the keyboard and are processed in the keyboard interrupt routine. If a new RVR channel has been requested, the new RVR channel number (0 to 9, A, or B) is displayed for 3 seconds. In an operational system, an additional set of displays could be used to permanently display the channel numbers. If the channel number has not changed since the last data update, then the channel number is not displayed. The received serial data are then formatted and transferred to the displays. Program execution then returns to the start of the main routine.

A simplified diagram of the serial interrupt routine is shown in figure 19. When a character is received by the USART, the CPU is interrupted. Program execution is directed to the serial interrupt routine where the character held by the USART is transferred to the CPU.

If the character is not an end of transmission (EOT) character it is stored in a memory location designated by a memory pointer. The character count and memory pointer are incremented by one and the program execution returns from the interrupt.

If an EOT is received, the character count is compared to 194 (the total number of characters transmitted by the Microcomputer SDC). If an error has occurred in transmission and the count is not 194, the character count is set to zero and the memory pointer points to the first location in the buffer. The

program execution returns from the interrupt. This procedure is a very crude check for data transmission errors. In an operational system, parity checks and a check sum should be used. If the character count is 194, then a flag is set to allow the main routine to update the displays. Program execution then returns from the interrupt.

When any button on the keypad is pushed, a PIO interrupt is generated and the parallel interrupt routine is entered. The character is input from the PIO and stored. It is then checked to see if it is a display character (C, D, or E) or an RVR character (0-9, A, or B). The display character indicates which display is to be selected. If the character is an RVR character, it is stored with the last display character selected. The result is that the desired RVR number will be stored in the desired display number. Also, bit 7 of the RVR character (not used otherwise) is set to indicate that the new channel number should be displayed for 3 seconds. Finally, the program is returned from the interrupt.

COMPARISON OF MICROCOMPUTER SDC VERSUS TASKER SYSTEMS RVR-500 MAINFRAME

The Tasker RVR-500 System is widely used at many of the largest airports and is considered one of the more sophisticated types in use. A single mainframe houses three separate SDC units plus a spare SDC unit. The spare may be used for checking the other three units and, in case of a failure, may be used as an immediate plug-in replacement for one of the other three.

The Tasker RVR-500 is an operational system; the microcomputer SDC is a laboratory model. A comparison of the two must take this into account. The following factors provide a comparison of the two systems. A summary of the comparison is presented in table 2.

1. Table look up methods are used for both systems. The RVR-500 Tasker table look up procedure is under hardware control, while the microcomputer procedure is under software control. Each RVR-500 SDC calculates the RVR value for one transmissometer, while the microcomputer can handle at least 12.

2. The RVR-500 System requires a 60-second delay in RVR calculations when switching between long and short baselines. The Microcomputer SDC allows for both long and short baseline systems to operate simultaneously.

3. The RVR-500 System performs self-checks to insure its reliability. This can be done for the Microcomputer SDC, but was not. On the other hand, the microcomputer performs tests on the transmissometer output not performed by the RVR-500. In this way, transmissometer projector and receiver errors can be determined more easily.

4. The RVR-500 System stores the transmissometer output on a single channel strip chart recorder. The microcomputer can provide similar recordings; however, its cassette storage medium allows for more data and more types of data to be stored. Similarly, the data displayed on the local terminal and transmissivity display exceeds the information displayed on the RVR-500 System. The RVR-500 System displays transmissivity as a percentage reading on a meter. On the front panel it displays RVR value, ambient light level, runway light intensity level, alarm status, and RVR change. The Microcomputer SDC provides all of these data, plus the transmissometer count, background count, and an alarm status word indicating the nature of the alarm.

5. Both systems output similar data to remote displays, but the approach is entirely different. The RVR-500 System uses a nonstandard serial transmission. Each serial line contains the RVR data for only one transmissometer.

TABLE 2. SYSTEM COMPARISON

Function	RVR/500	Micro
Method of calculation	Table look up	Table look up
No. of transmissometers	3	12 (capable of being expanded to more than 20)
Long/short baseline	Switches from one baseline receiver to the other	Each transmissometer receiver is a separate input channel with software determining whether long or short table is used
External alarm checks	RVR minimum	RVR minimum, transmissometer minimum, transmissometer maximum, background maximum
Internal alarm checks	Counters using spare system self-check	None (counter checks and system self-checks can be added)
Data storage capability	Strip chart recorder for transmissivity on a single channel	Cassette tape recorder can store any or all data (RVR values, transmissivity, etc.) for all channels; strip chart data outputs are also available
Transmissivity data	Current sensitive analog meter	LED bar graphs
Data display	Digital display and status lights on SDC front panel	CRT display (digital displays can be added)
Data entry	Front panel, thumb-wheel switches, push buttons, etc.	CRT terminal keyboard
Output format	Serial tone signals, one signal per SDC	RS-232 serial - all data on one channel
Remote display	RVR-500 remote displays only	Any RS-232 compatible receiver
Design flexibility	None	Software modifiable
Cost	Doubles if more than three channels are required, triples if more than six are required, etc.	Fixed

Therefore, many serial lines are required at airports having several RVR units. The Microcomputer SDC outputs all data over a single RS-232 serial channel. Modems may be used to enable data to be transmitted any distance. Although the data are sent to a remote display, it can just as easily be sent to a CCD system central computer, a modem, or any other computer system with an RS-232 serial channel.

6. The Tasker RVR-500 is a hardware-based system. Any modifications to improve performance require hardware changes. The Microcomputer SDC is a software-controlled system. Many changes can be accomplished by modifications to the system software.

It is difficult to compare the cost of a production item such as the Tasker RVR-500 System and a laboratory device such as the Microcomputer SDC. The Tasker RVR-500 mainframe, with four SDC units, costs about $10,000. Parts for the Microcomputer SDC and the local terminal CRT cost less than half that amount. Using the microcomputer could provide significant cost savings at airports using more than one Tasker RVR-500 System.

To summarize, the Microcomputer SDC performs all the functions of a Tasker RVR-500 SDC except for self-checking, which can be added. In addition, the Microcomputer SDC is capable of large data storage, transmissometer alarm checking, standardized data transmission, and simultaneous long and short baseline calculations. Cost comparisons are difficult, but a significant cost savings could be achieved if the Microcomputer SDC is used in airports having more than three transmissometers.

ANALYSIS

The basic RVR System (i.e., transmissometers, SDC's, and remote displays) has been used for more than 30 years. Sophisticated light sources, receivers, and electronics are now available to totally redesign the RVR System; however, development, procurement, and installation of a new system involves considerable cost and time. The Microcomputer SDC is not necessarily intended as part of a new system, but as an inexpensive way of getting more out of the existing system.

From the FAA's Facility Data Base, approximately 100 of the over 400 SDC's in use are Tasker RVR-500's. Most of the remaining SDC's are older and have a more limited performance capability. Many of these older systems may require replacement long before a totally new RVR System is available. The Microcomputer SDC could provide a cost effective interim replacement.

One possible way of implementing the replacement program would be to install Microcomputer SDC's at airports using more than three transmissometers. In the United States there are approximately 25 airports in this category. At those airports using Tasker RVR-500's, the RVR-500's could be removed and used to replace older RVR's at smaller airports. In this way, the purchase of one Microcomputer SDC could provide an improvement at several airports.

Installation of a stand-alone Microcomputer SDC would also require new remote displays. A remote display similar in design to the one presented here, but of smaller size and lower costs, can be used. Such a device will not significantly detract from the overall cost benefit. The Microcomputer SDC can use the existing strip chart recorders for data storage; however, a cassette recorder would provide much greater data storage capacity for a small price.

A more limited way of replacing SDC's would be to integrate the microcomputer into the Consolidated Cab Display (CCD)

System. About 40 airports are planned to receive CCD Systems. Since the CCD System has its own displays and data storage system, only the Microcomputer SDC is required.

CONCLUSIONS

The Microcomputer Signal Data Converter (SDC) was not designed for field installation, but was designed to demonstrate the feasibility of using a microcomputer as an SDC. The following conclusions can be drawn based on this Microcomputer SDC design effort.

1. The Microcomputer SDC can perform all the tasks performed by any of the widely used SDC's.

2. The Microcomputer SDC can provide additional functions such as alarm checking and simultaneous long and short baseline Runway Visual Range (RVR) calculations.

3. One Microcomputer SDC can serve an entire airport, regardless of the number of transmissometers in use.

4. A single bulk storage unit, such as a cassette tape recorder, can be used to store all relevant RVR data. Strip chart recorder interfaces are also available, but unnecessary.

5. Most of the Microcomputer SDC hardware used off-the-shelf printed circuit boards. A field operational Microcomputer SDC would require only custom made designs for transmissometer pulse signal conditioning and for the transmissometer counter circuitry.

6. Most Microcomputer SDC operations are carried out by software. Therefore, many system modifications and improvements can be performed without hardware changes being required.

7. By transmitting RVR data through RS-232 serial data channels, RVR data can be received by any device having an RS-232 interface. In this way, the Microcomputer SDC can send data to remote displays, a CCD central computer, or any other computer system or terminal with an RS-232 interface. By using modems, the RVR data can be sent any distance to remote facilities.

8. Significant cost savings can be achieved by installing Microcomputer SDC's at airports having a large number of transmissometers.

RECOMMENDATIONS

Based on the microcomputer design effort, the following recommendations are made:

1. The Microcomputer Runway Visual Range (RVR) task should be expanded to include the development of a full stand-alone RVR system. In addition to the Signal Data Converter (SDC), this system would include signal conditioning and a low cost compact remote display.

2. All airports scheduled to have a Consolidated Cab Display (CCD) System installed should also have a Microcomputer SDC installed. If Tasker RVR-500 units are currently at these airports, they should be moved to airports having older RVR units.

3. Based on successful completion of field tests of a stand-alone system, all other airports using more than three transmissometers should have Microcomputer SDC's installed.

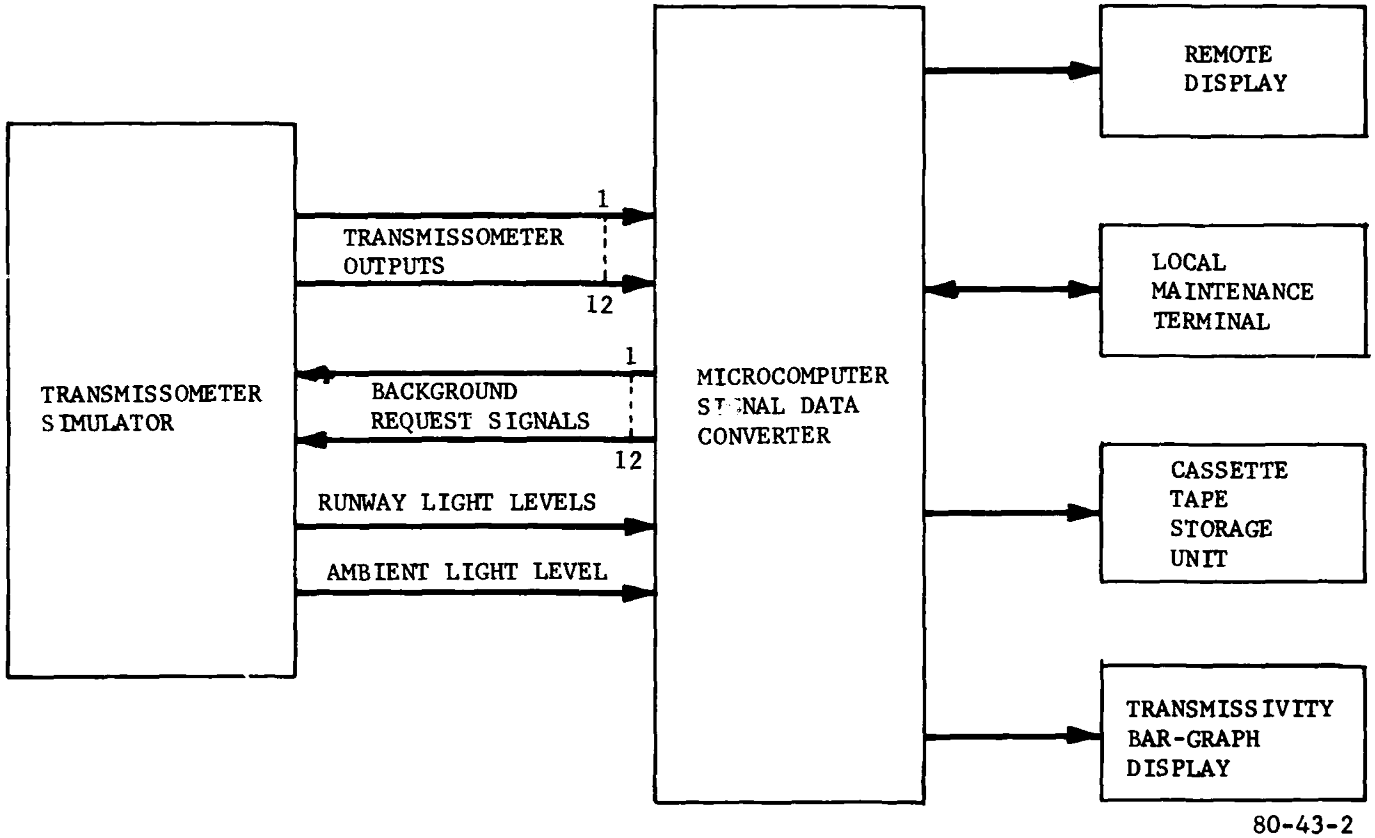

FIGURE 2. MICROCOMPUTER-BASED RVR SYSTEM, BLOCK DIAGRAM

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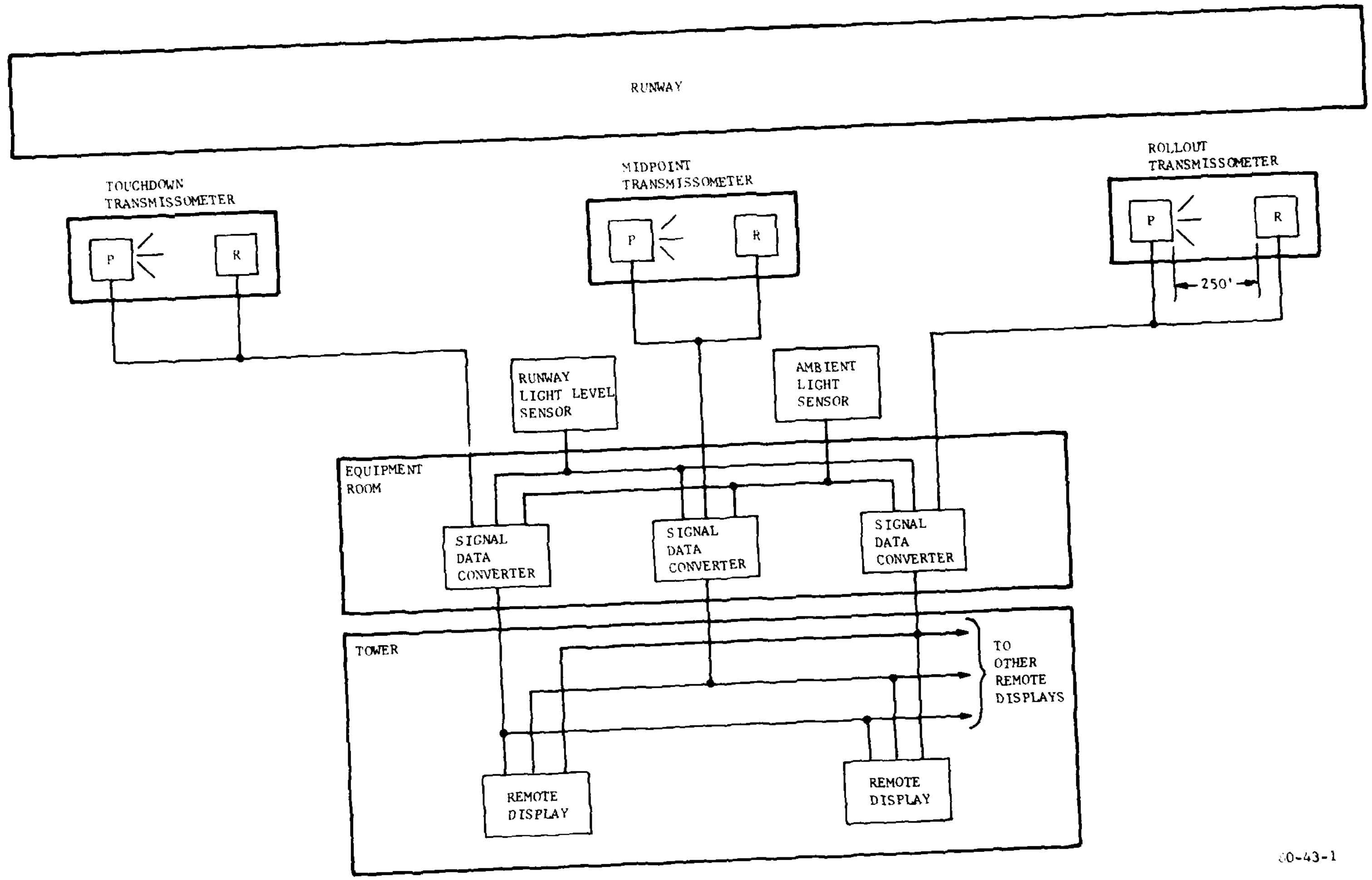

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FIGURE 1. TYPICAL RVR SYSTEM, BLOCK DIAGRAM

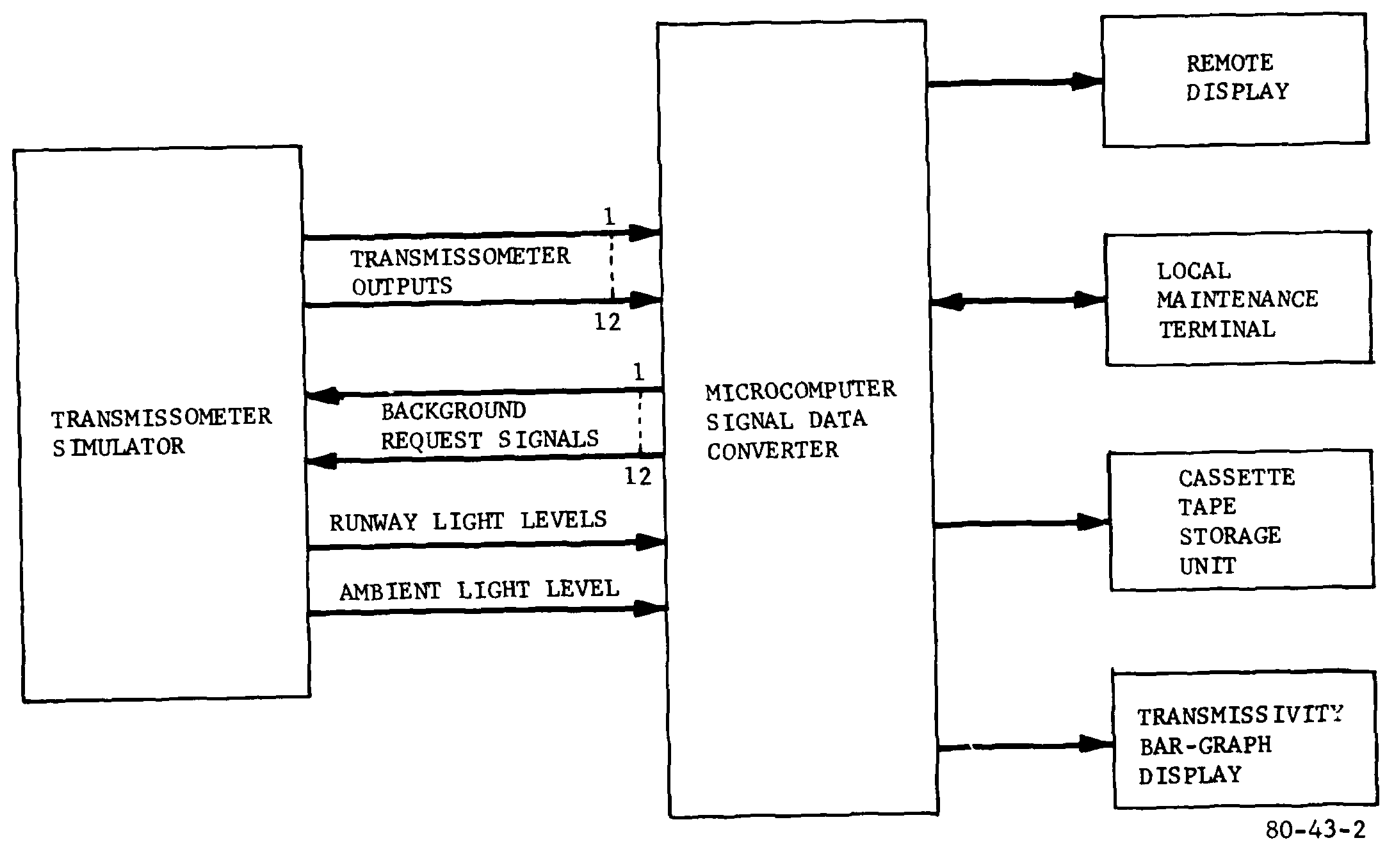

FIGURE 2. MICROCOMPUTER-BASED RVR SYSTEM, BLOCK DIAGRAM

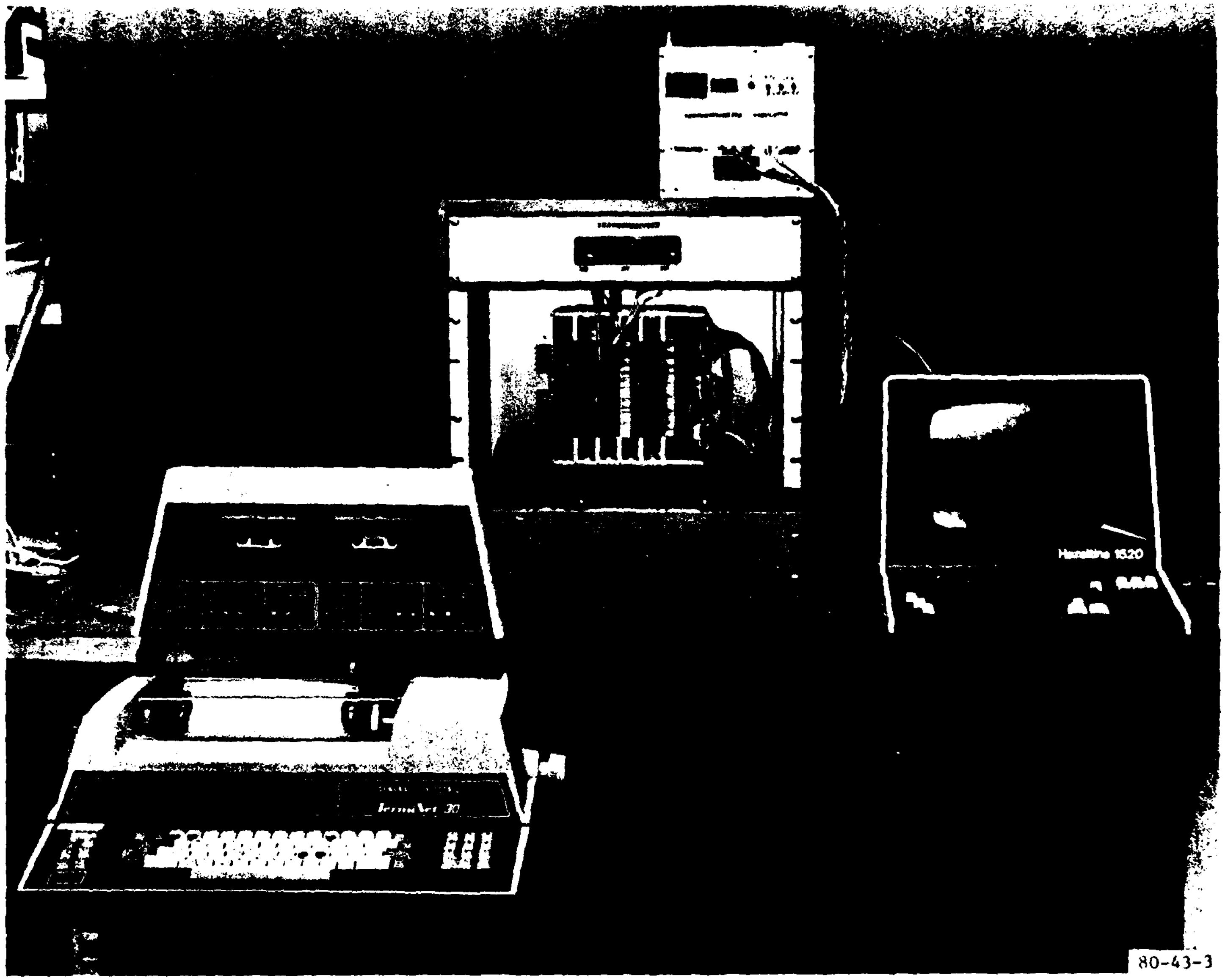

FIGURE 3. MICROCOMPUTER SDC, LED BAR-GRAPH DISPLAY, LOCAL MAINTENANCE TERMINAL, AND CASSETTE STORAGE UNIT

FIGURE 4. TRANSMISSOMETER SIMULATOR

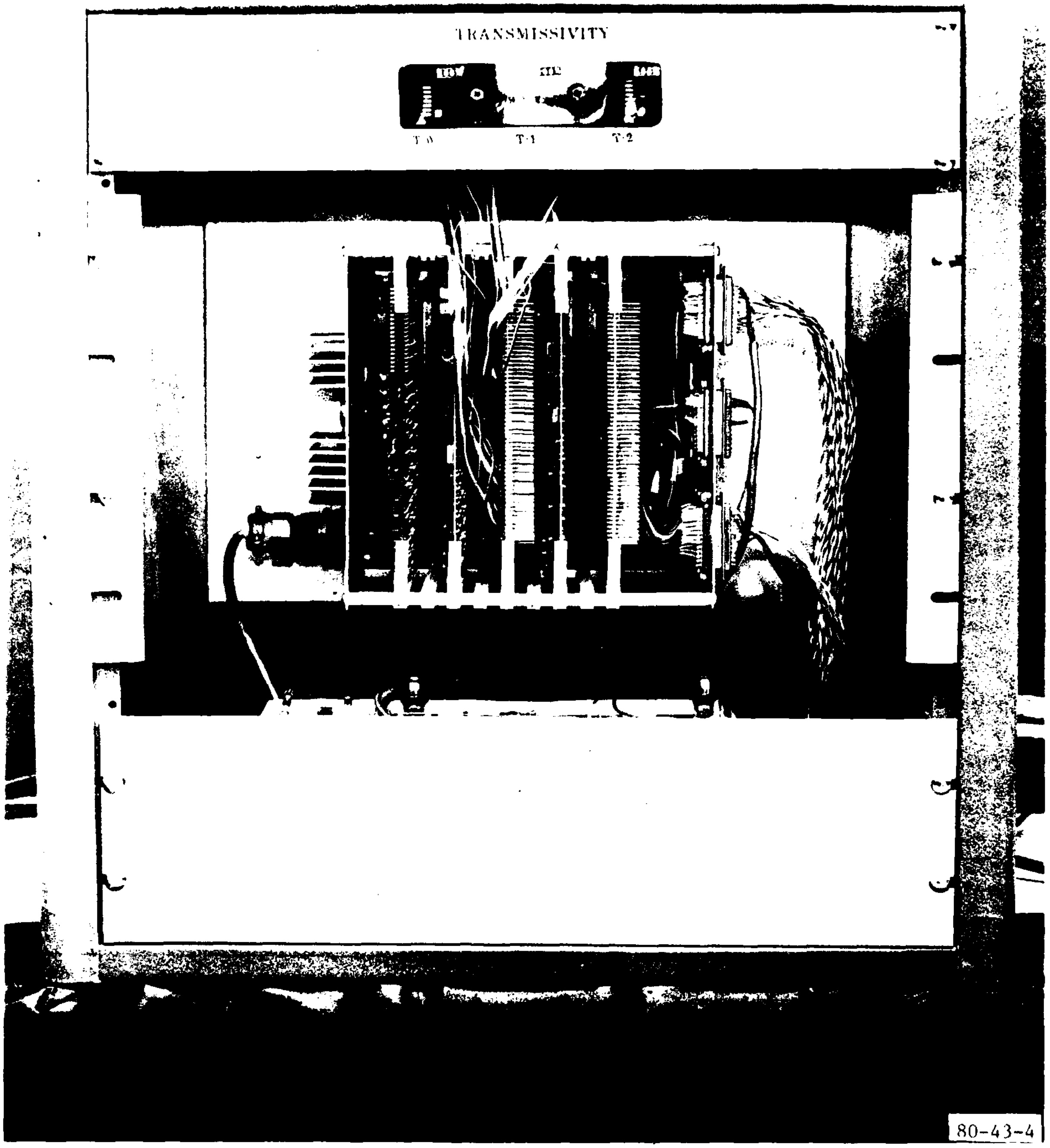

FIGURE 5. MICROCOMPUTER SDC AND LED BAR GRAPH DISPLAY

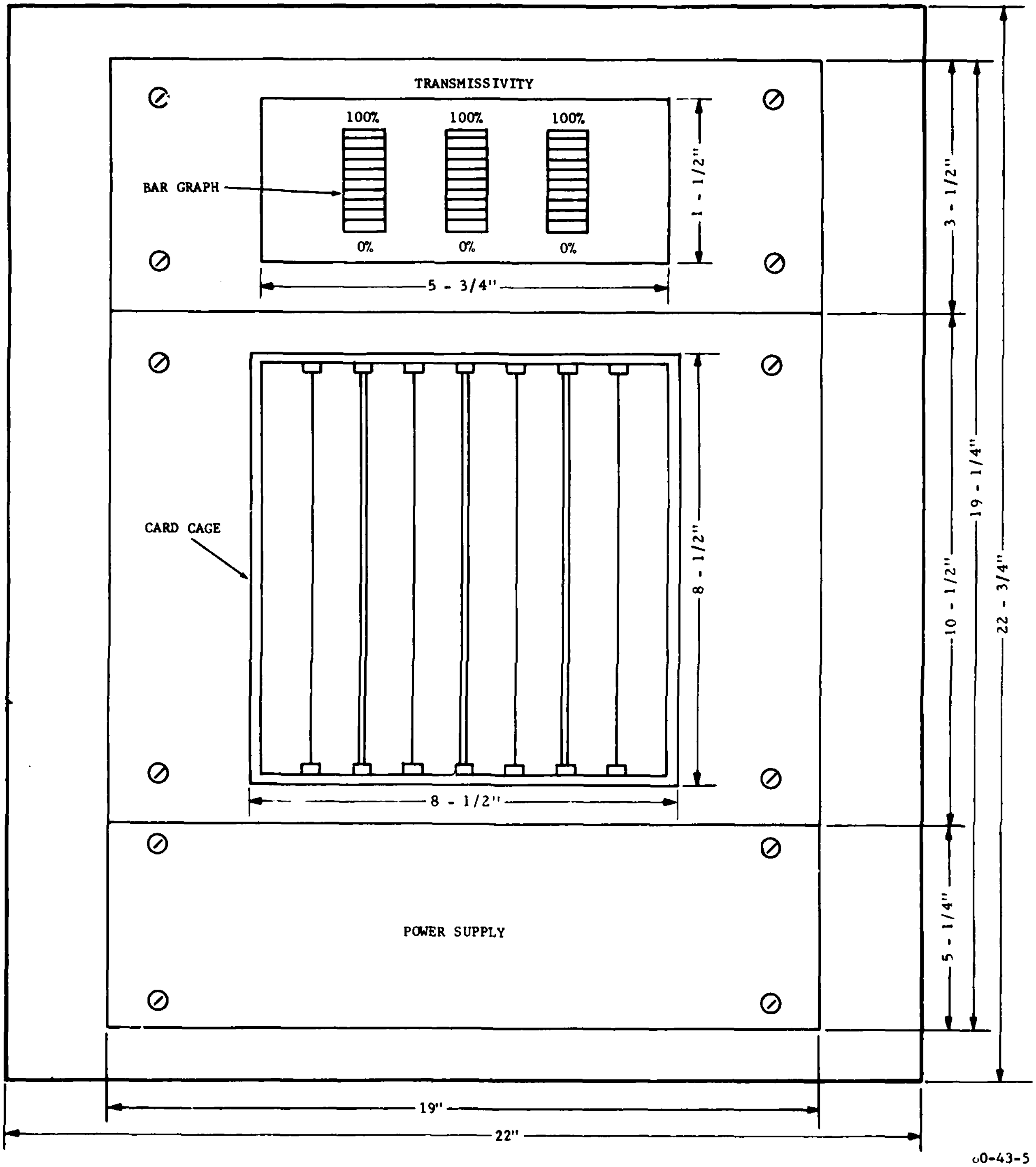

FIGURE 6. MICROCOMPUTER SDC AND LED BAR GRAPH DISPLAY MECHANICAL LAYOUT

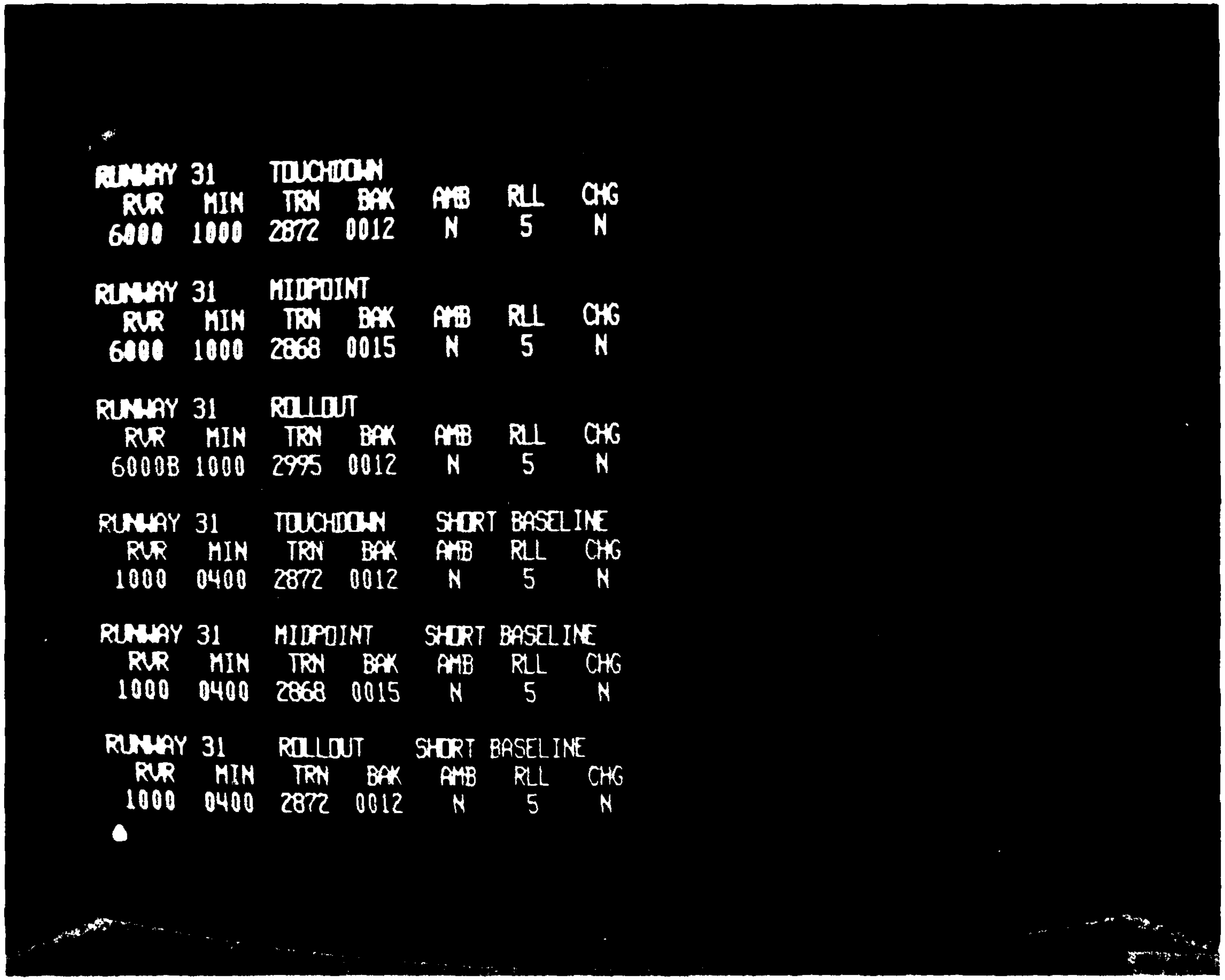

FIGURE 7. LOCAL MAINTENANCE TERMINAL DISPLAY

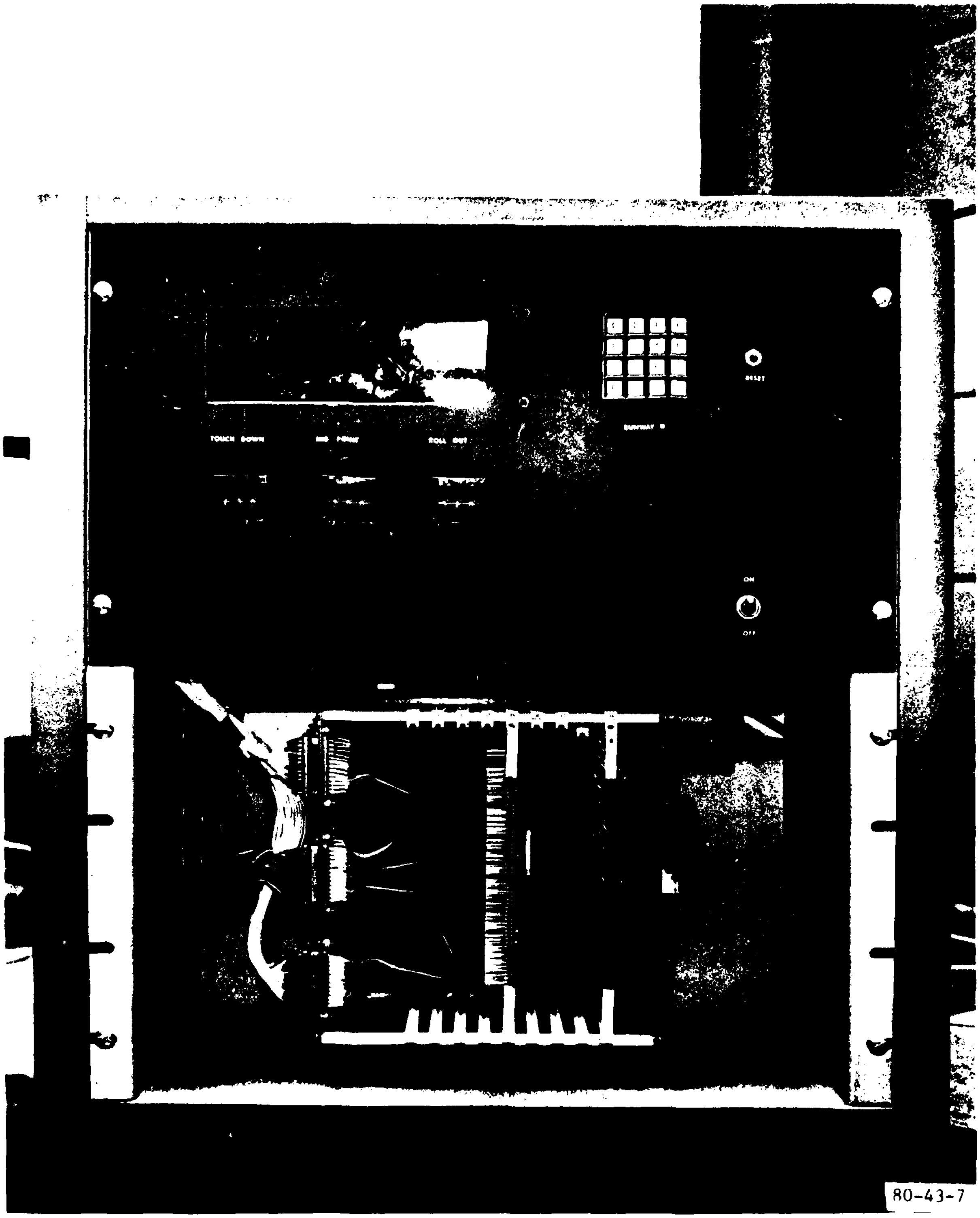

FIGURE 8. REMOTE DISPLAY UNIT

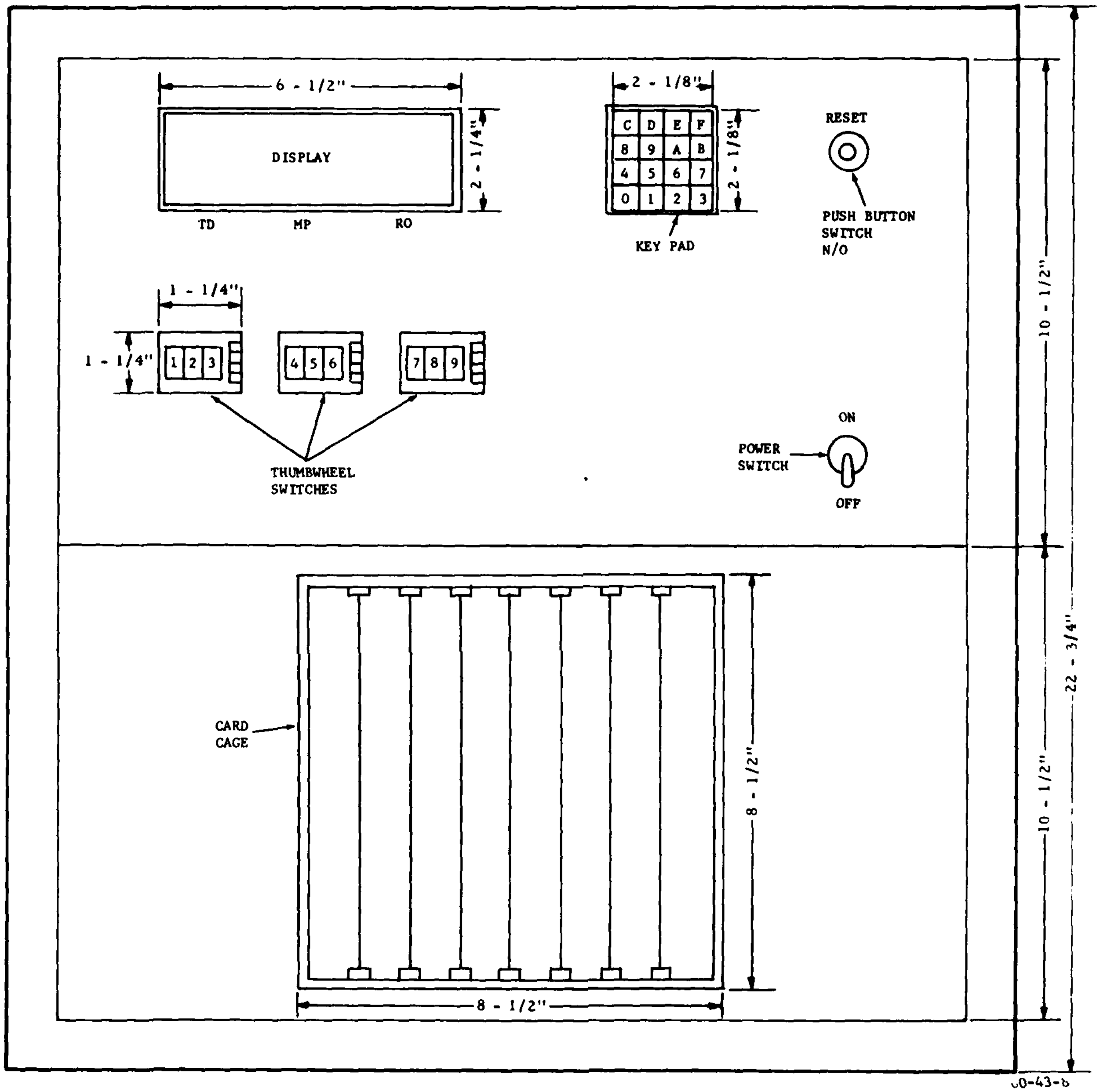

FIGURE 9. REMOTE DISPLAY UNIT MECHANICAL LAYOUT

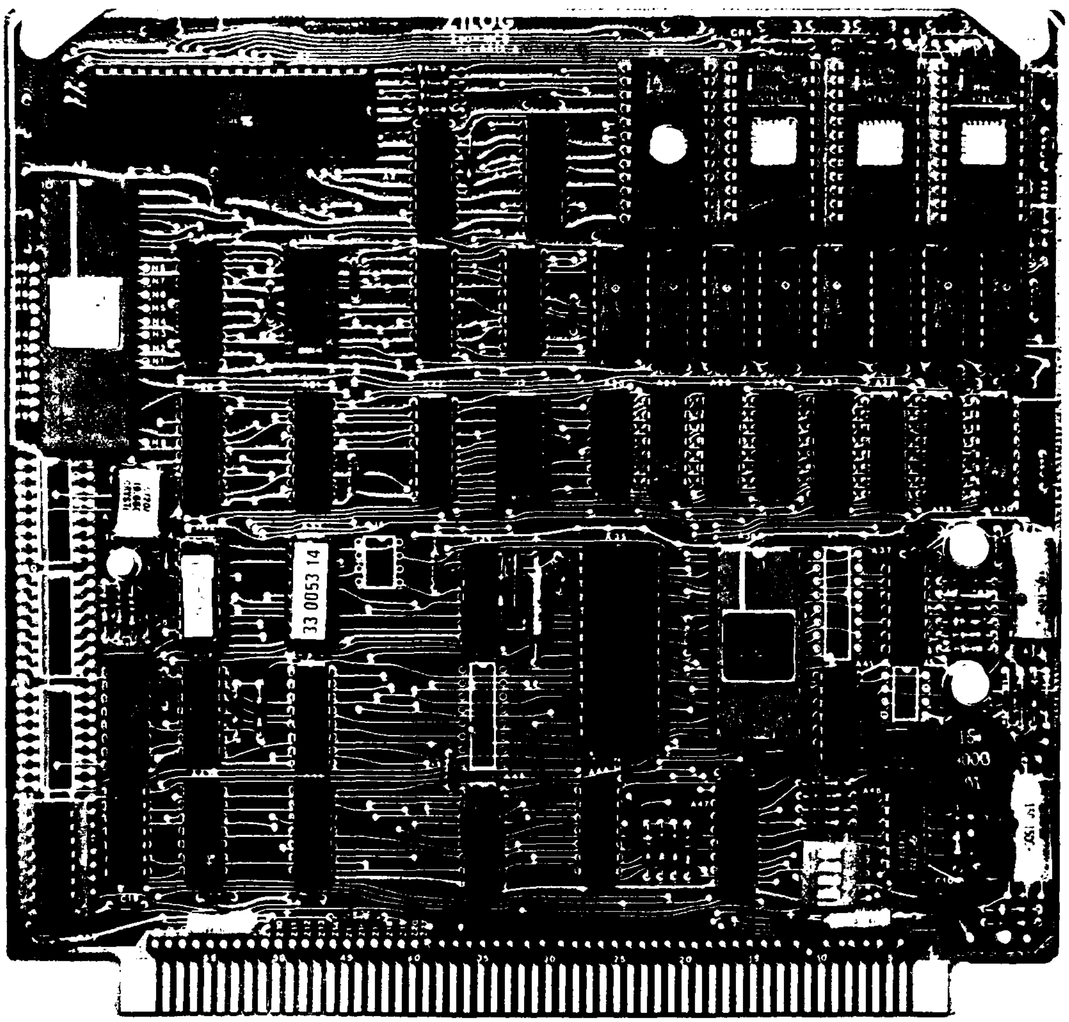

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FIGURE 10. ZILOG MICROMPUTER BOARD

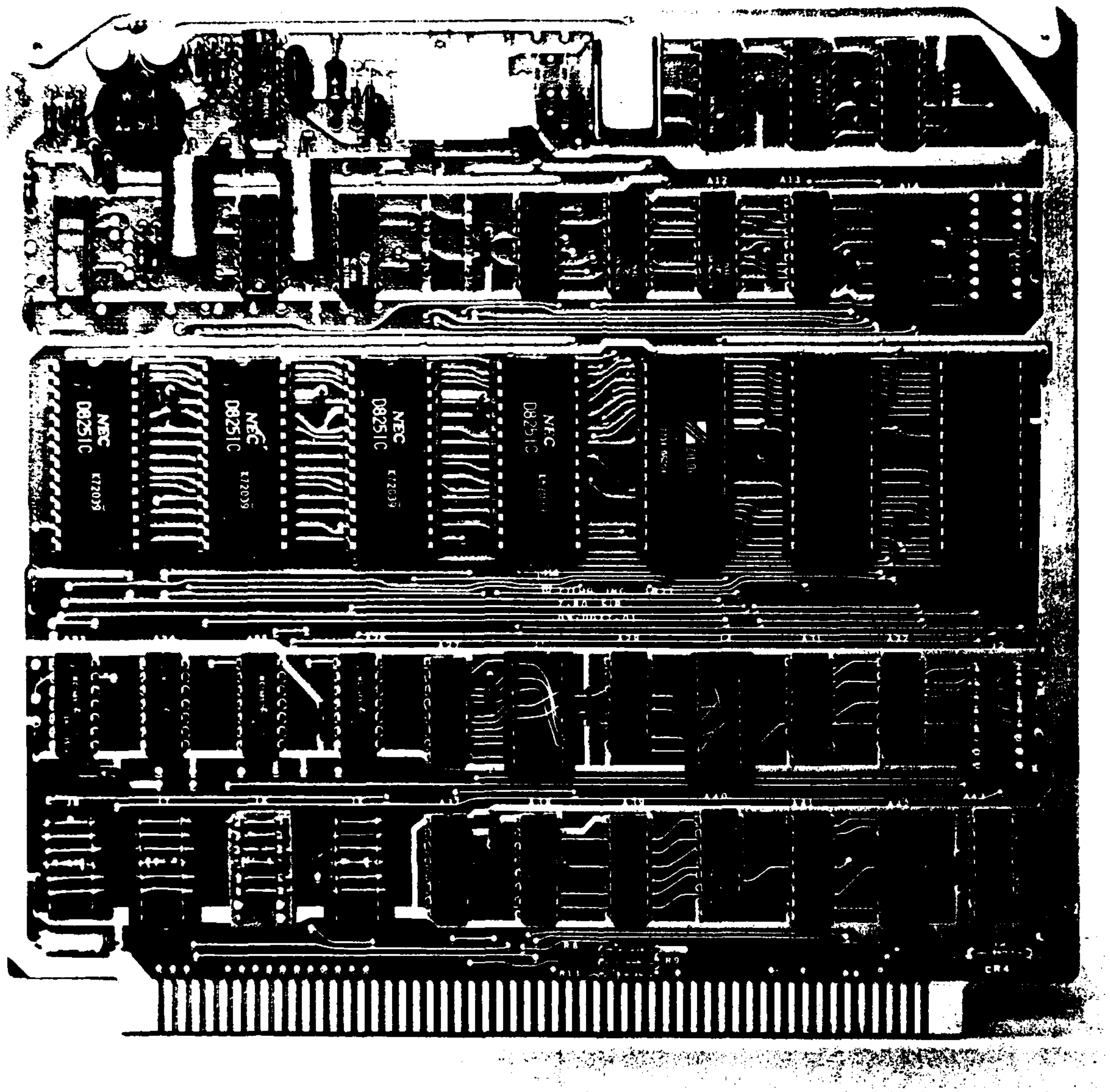

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FIGURE 11. ZILOG SERIAL INTERFACE BOARD

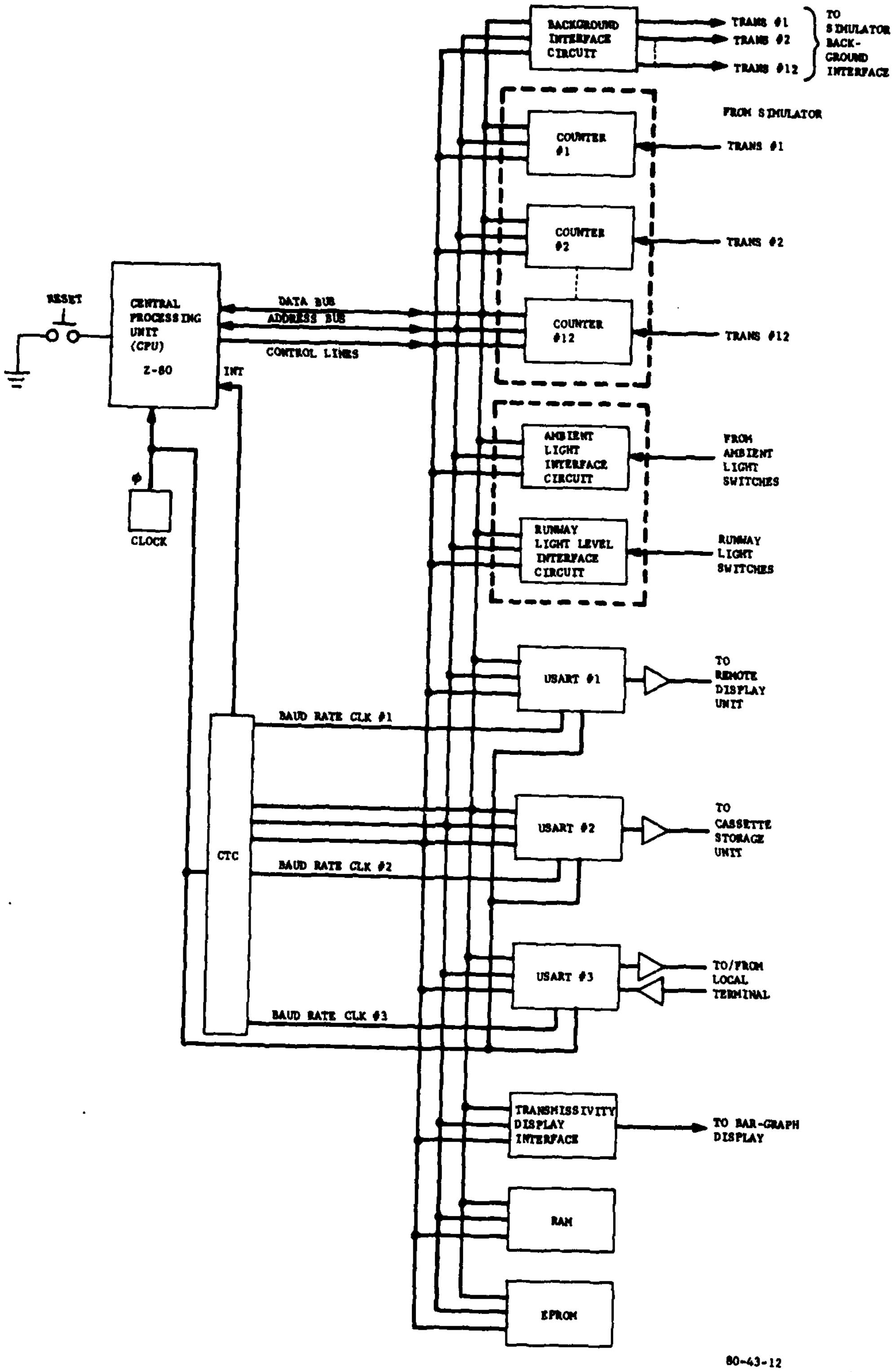

FIGURE 12. MICROCOMPUTER SDC BLOCK DIAGRAM

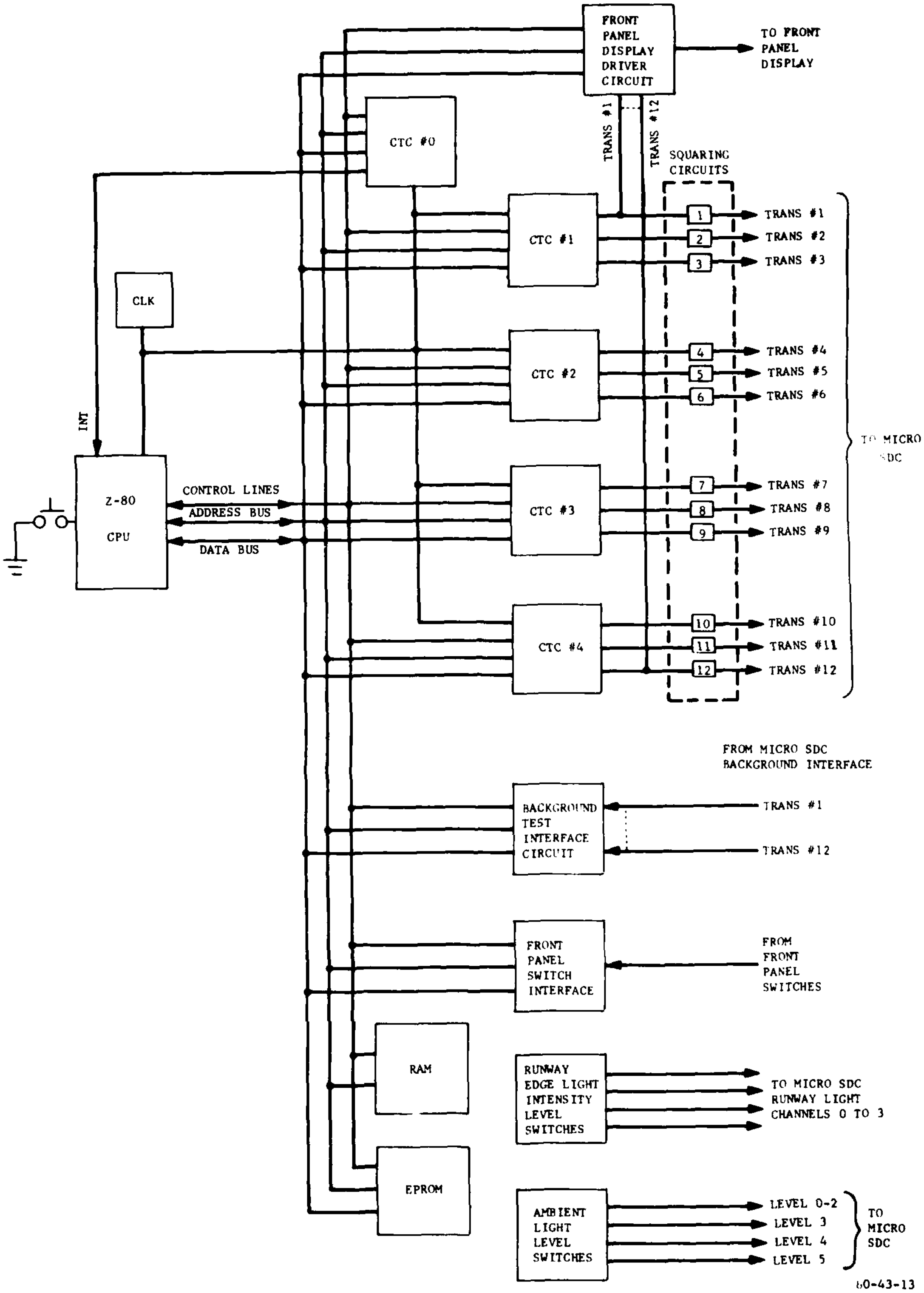

FIGURE 13. TRANSMISSOMETER SIMULATOR BLOCK DIAGRAM

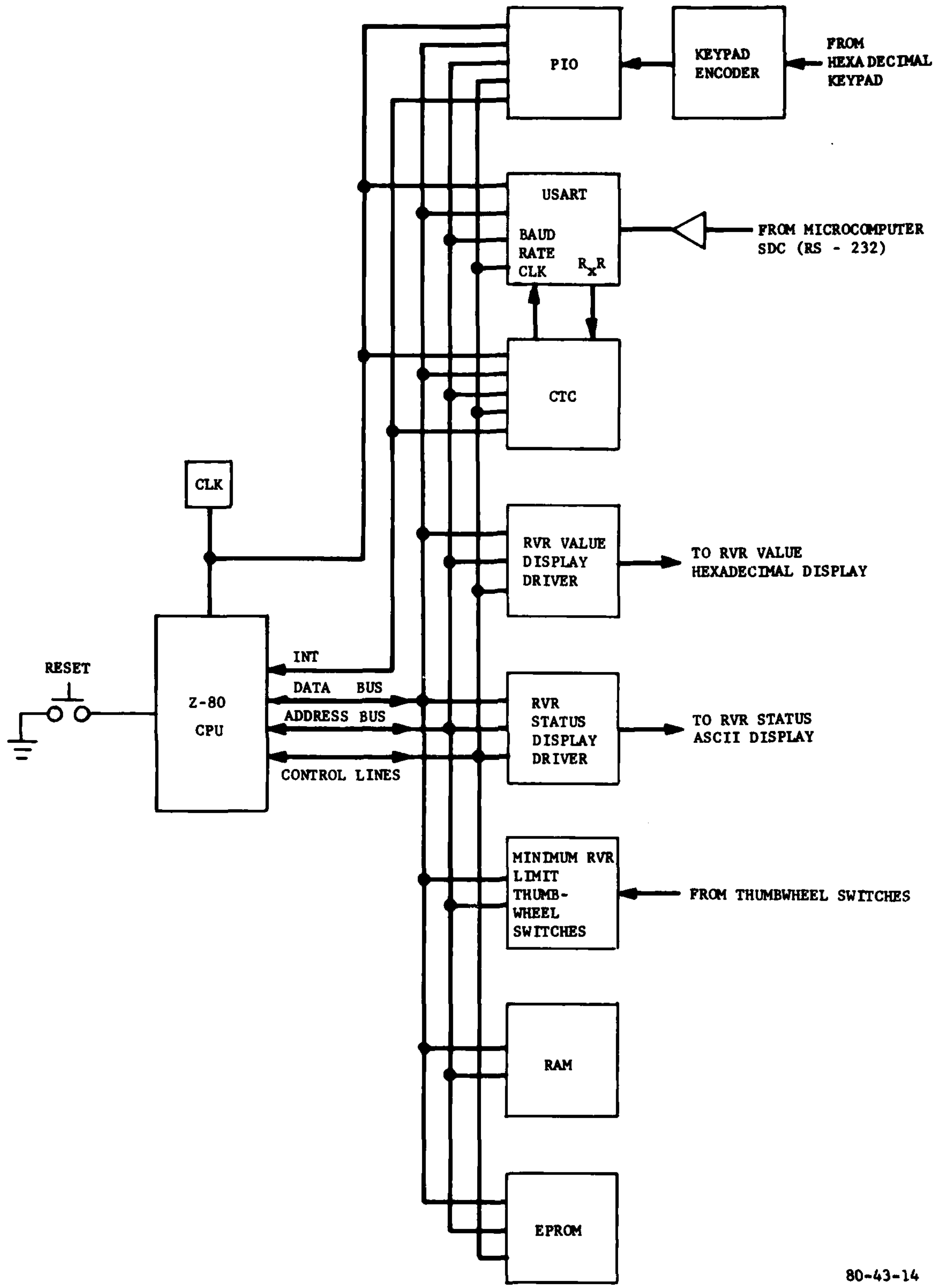

FIGURE 14. REMOTE DISPLAY BLOCK DIAGRAM

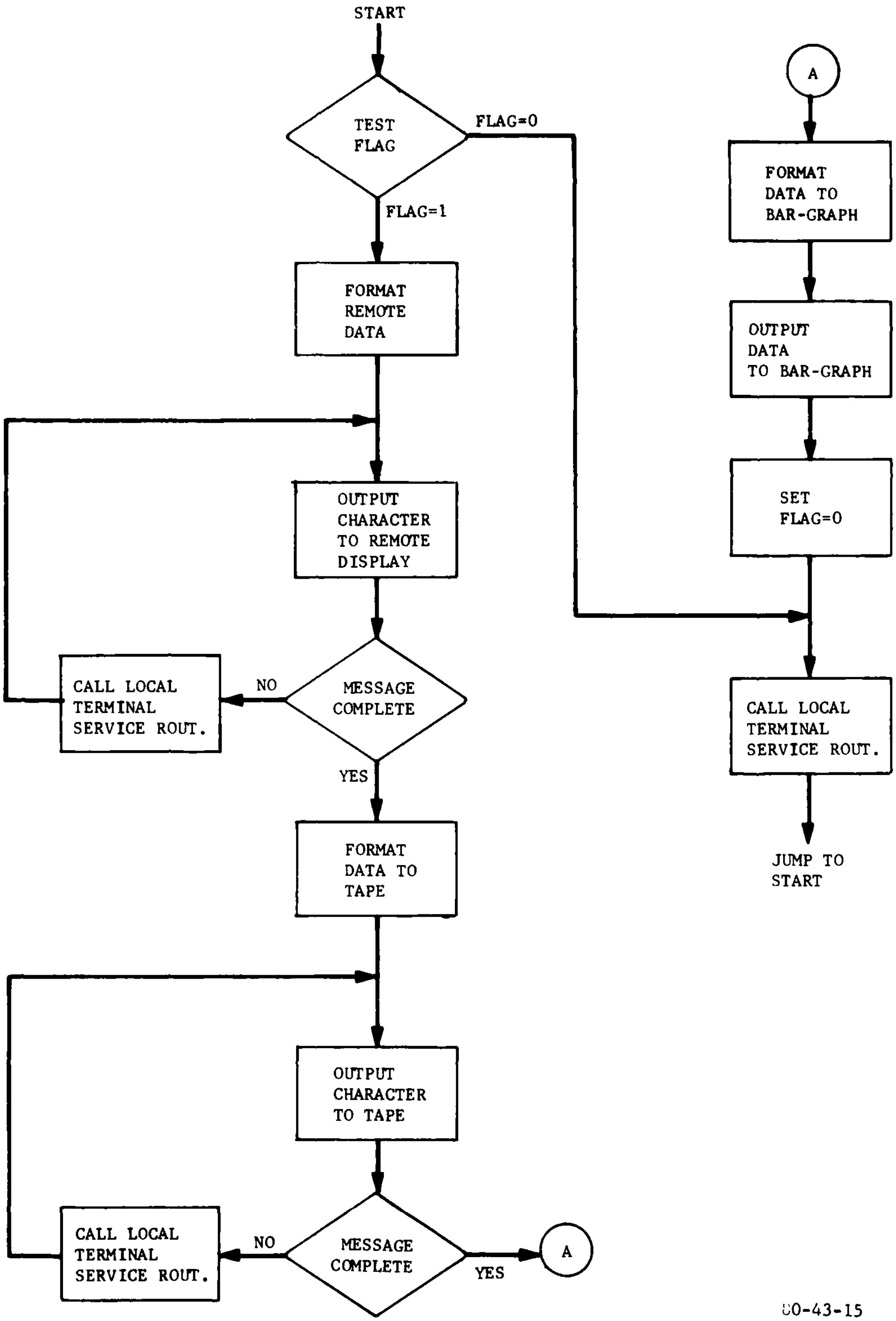

FIGURE 15. MAIN ROUTINE

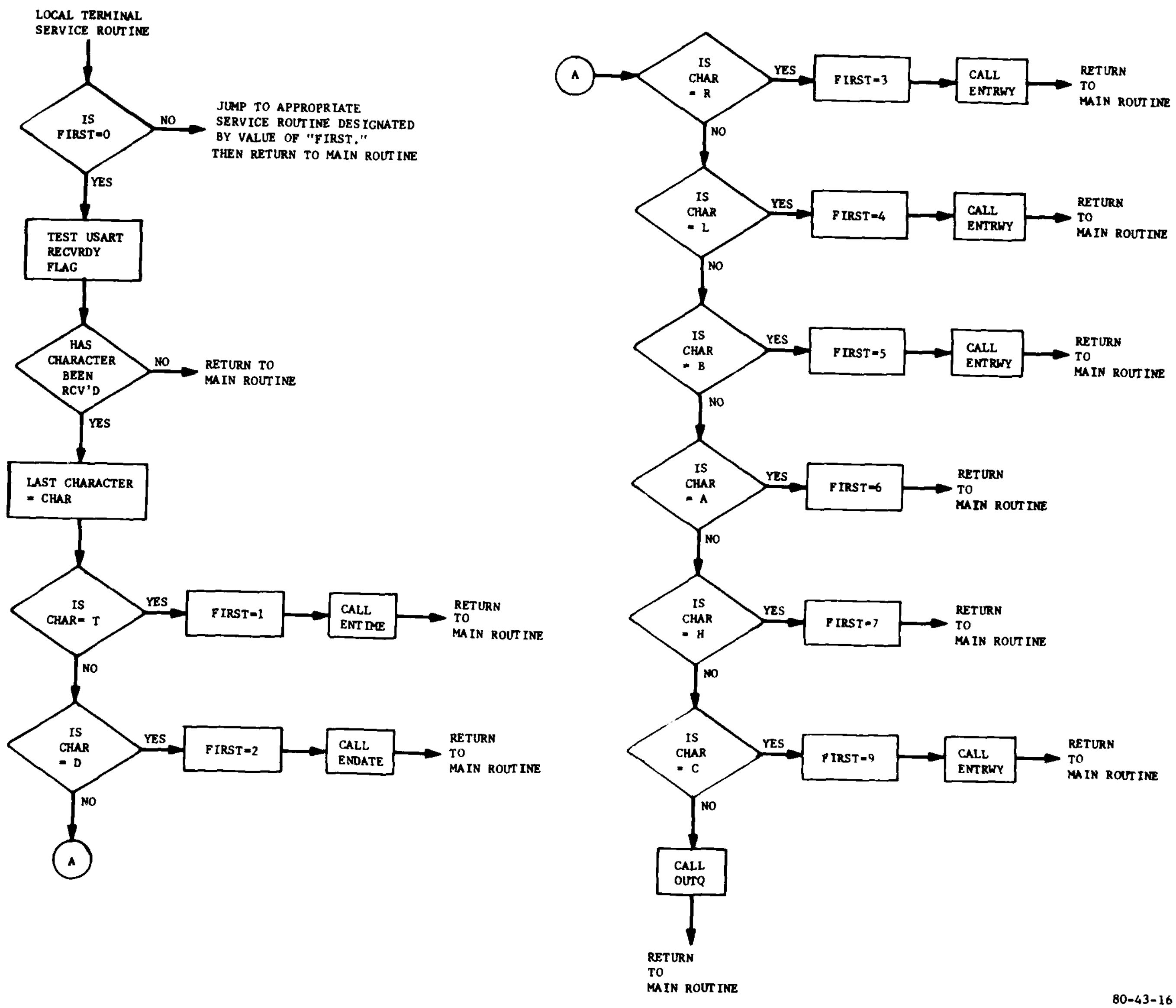

FIGURE 16. LOCAL TERMINAL SERVICE ROUTINE

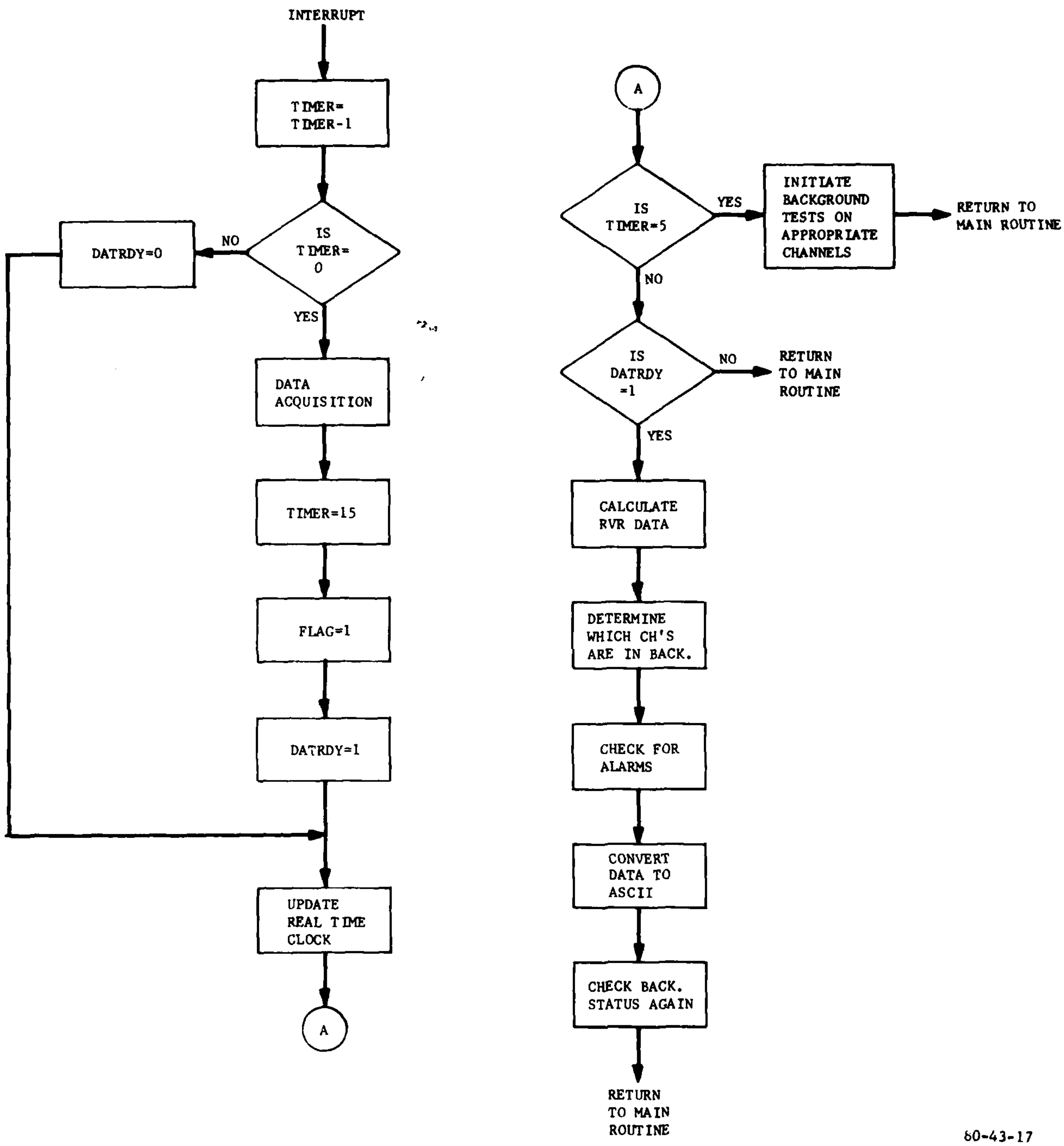

FIGURE 17. INTERRUPT SERVICE ROUTINE

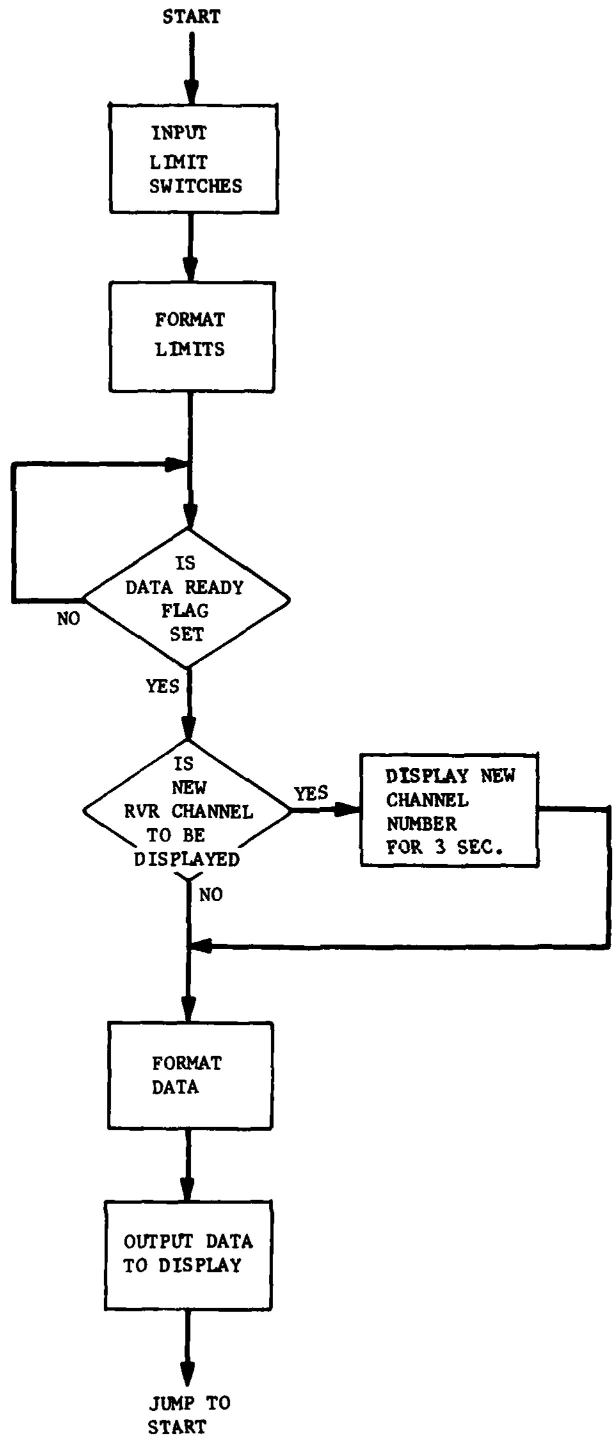

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FIGURE 18. REMOTE DISPLAY MAIN ROUTINE

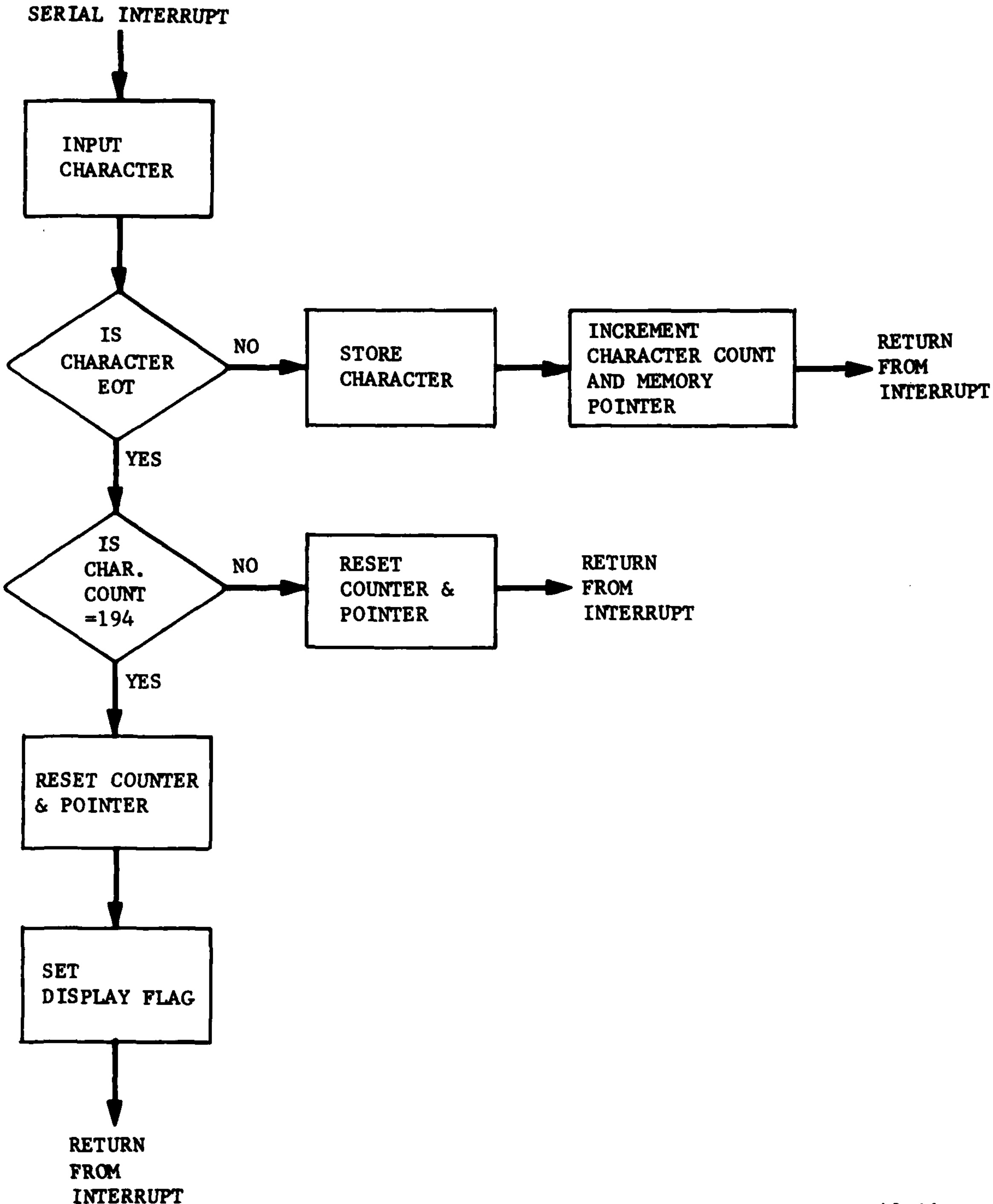

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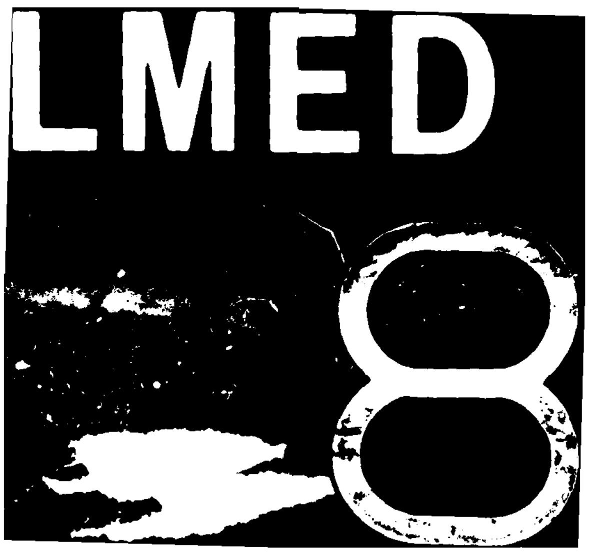
FIGURE 19. SERIAL INTERRUPT ROUTINE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